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Corn Borer Control on Sweet Corn with Concentrated Sprays

J. W. APPLE[1] and G. C. DECKER[2,3]

The term concentrated spray as used in this paper, refers to a spray mixture which contains the amount of insecticide required for one acre in 2 to 5 gallons of liquid.

The first evaluation of such a spray against the European corn borer, *Pyrausta nubilalis*, (Hbn.), was made by Batchelder & Questel (1945). These workers formulated an oil solution containing 9 per cent DDT and applied it by plane at the rate of 2.25 gallons to the acre. Four applications of such a spray resulted in 92.5 per cent corn borer reduction on sweet corn. Decker *et al.* (1947) also reported exceptionally high corn borer control by the use of DDT in oil solution. Their work was done on sweet corn where the concentrated sprays were applied by aircraft.

Bigger *et al.* (1947) obtained 92.2 per cent corn borer control on field corn by aerial application of 2 gallons per acre of an oil solution containing 0.5 pound of DDT to the gallon. These authors stated that the oil spray caused a slight reduction in yield.

These early findings indicated considerable promise for this type of spray for corn borer control and prompted the authors to undertake the investigations reported in this paper. An intensive study of numerous sprays cannot be undertaken very easily by the use of aerial equipment because of the need for very large plots and large supplies of spray ingredients. For these reasons, studies were carried on with ground sprayers equipped with nozzles of very low capacity. As these investigations developed, it became apparent that the findings would be applicable to corn spraying with ground equipment adapted from typical weed sprayers as well as to aerial application of concentrated sprays for corn borer control.

EQUIPMENT.—The spray equipment used in these studies was mounted on high clearance detasselers so that corn of all heights might be sprayed. One of the sprayers used in the 1947 investigations was a compressed air type of sprayer provided with a four row boom having two fan nozzles[4] to the row. Nozzles were adjusted to apply the spray primarily to the ear zone. This sprayer was operated at a pressure of 35 pounds. The second sprayer used in 1947 was an experimental hydraulic-pneumatic atomizing sprayer equipped with a 10-row boom having three nozzles[5] to the row. Spraying with this machine was accomplished with very low liquid (3.5 & 5 pounds) and air (9 & 13 pounds) pressures. The finely atomized spray emitted by this sprayer provided very thorough plant coverage.

The sprayer used in the 1948 studies was a modification of the compressed air sprayer used the previous year. During the first year of operation the liquids were carried in a 65 gallon tank and each spray had to be removed and the tank thoroughly drained before the next solution or emulsion was added. Rust from the inside of the tank caused considerable clogging of the small orifice nozzles. To do away with these handicaps and to speed-up spraying operations, the sprayer was redesigned for the 1948 tests so that the tank served only as a reservoir for the compressed air and the spray liquids were car-

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[3] The authors wish to thank C. W. Kearns of the Dept. of Entomology, Univ. of Illinois for helpful suggestions and the California Packing Corp. of Rochelle, Illinois for providing experimental fields.
[4] *Teejet 500050.*
[5] *Spray Systems Pneumatic Set-Up 50.*

ried in separate 3-gallon copper tanks mounted on the side of the detasseler. Between treatments, it was only necessary to blow the excess spray from the boom and change the air and liquid lines to a new tank of spray. This technique did not provide agitation to the spray liquids but this was no handicap since all sprays were either solutions or emulsions.

Sprays were applied in 1948 with either two fan nozzles[1] or three hollow cone nozzles[2] to the row. Spraying pressures varied from 28 to 70 pounds depending on the spray ingredients and nozzles employed.

During the second year of these investigations, concentrated sprays were compared with a conventional spray whereby the insecticide was applied at a pressure of 200 p.s.i. by means of a piston-displacement pump using three nozzles per row

SPRAY INGREDIENTS —The initial work with concentrated sprays for corn borer control showed that DDT in oil solution was highly effective However, the early investigations with this type of spray demonstrated that appreciable injury to corn might result from the use of a DDT co-solvent in the preparation In the present studies, the authors attempted to evaluate the phytotoxicity as well as the toxicity to corn borers of DDT solutions prepared with various co-solvents and base oils. The solubility of DDT in the co-solvents and base oils used in insecticidal oil solutions is given in table 1 along with code letters which will be used for subsequent identification of spray ingredients.

Oil solutions of DDT were formulated for the most part on the basis of 0.5 pound of DDT per gallon of finished spray. Three gallons of such a spray to the acre provided 1.5 pounds of toxicant. Since the base oils used in these formulations have the ability to dissolve various amounts of DDT, the quantity of co-solvent needed to dissolve the remainder of the insecticide would naturally vary in amount. Likewise, the co-solvents themselves varied in their solubility properties and would therefore be used in different amounts to dissolve an equal amount of DDT. In most cases, the quantity of co-solvent employed was no greater than that necessary to hold the toxicant in solution at normal summer temperatures. While this approach to the formulation of insecticidal sprays is not practical under conditions of year-around storage, it did provide a means for reducing the degree of plant injury.

Table 1.—Solubility of DDT in co-solvents and base oils used in the preparation of insecticidal-oil sprays.

CO-SOLVENTS	Gm. DDT per 100 ml. 26.7° C.
A. *Velsicol AR 60*	57
B. *Velsicol AR 50G*	60
C. *Sun Solvent 3*	44
D. *Shell Solvent E-407*	40
E. *Amsco 550*	57
F. *Indocene 90*	40
G. Carbon tetrachloride	45
H. Cyclohexanone	120

BASE OILS	Gm. DDT per 100 ml. 26.7° C.
AA. *Superla 13 horticultural oil*	3.7
BB. *Shell horticultural spray base No. 7*	4.2
CC. *Sun 30737-B lubricating oil*	4.2
DD. *Apco 700 naptha*	4.4
EE. Mineral seal lubricating oil	6 1

DDT emulsions were employed throughout these tests as a standard treatment since this type of spray is adapatable to a wide range of dilutions. A DDT emulsifiable concentrate prepared with a volatile solvent was used because of its greater safety on corn foliage.

In addition to DDT, the following insecticides were evaluated in one or more types of spray; dichlorodiphenyl dichloroethane, toxaphene, chlordane, heptachlor, aldrin, parathion, *Ryania*, and mixtures of rotenone plus piperonyl butoxide and rotenone plus pyrethrins with piperonyl butoxide.

1947 EXPERIMENTS.—The first evaluation of concentrated sprays applied by ground machines for corn borer control was made against the second generation borer in northern Illinois during August, 1947. Two experiments were conducted in the same 120 acre field of yellow canning corn. This particular field was planted on June 24 and was just beginning to silk at the time of the first application. The initial application was timed to coincide with the beginning of egg hatching. Egg deposition

[1] *Teejet 650067.*
[2] *Teejet No. 127.*

reached a maximum of 590 egg masses per 100 plants.

Insecticidal applications were made August 22 and 27 in both 1947 experiments. A third application was planned for September 1 or 2 but this schedule was not completed because the corn lodged very severely following a storm on August 29. Since dissection records were not taken until September 12, an interval of 16 days elapsed between the last application and harvest, which no doubt contributed to the relatively poor corn borer control obtained in the 1947 experiments.

The first of the 1947 experiments was an evaluation of 12 concentrated sprays applied with the compressed air sprayer. Plots were 8 rows wide and 80 rods long. Each treatment was duplicated in a second block or replicate. Thirty plants were selected at random from each plot at harvest time and dissected to determine the surviving corn borer population. The results obtained in this first experiment are shown in table 2.

The second experiment conducted in 1947 was an evaluation of the hydraulic-pneumatic atomizing sprayer for second generation corn borer control on canning sweet corn. An oil solution of DDT containing 0.33 pound of DDT per gallon of base oil BB was applied at two combinations of liquid and air pressure. Three rates of application at each pressure setting were made by adjusting the travel speed of the sprayer.

Individual plots in this experiment were ten rows wide (width of boom) and 40 rods long. The six treatments were replicated in a second block. The results of this experiment as shown in table 3 are based on the corn borers surviving in 20 plants taken from each plot at harvest time.

Table 3.—Second generation corn borer populations on canning sweet corn following two applications of DDT-oil solution[1] applied with an atomizing sprayer.

Spraying Pressures		Gals. per Acre	Pounds DDT per Acre	Borers per 100 Plants[2]
Lbs. Liquid	Lbs. Air			
5	9	4	1.33	270
5	9	3	1.00	310
5	9	2.5	0.83	495
3.5	13	4	1.33	405
3.5	13	3	1.00	455
3.5	13	2.5	0.83	400
				not significant

[1] DDT-oil solution contained 0.33 pound of DDT per gallon of base oil BB.
[2] The 1170 corn borers per 100 plants reported in the untreated plots of the previous test might be compared to the populations in this test since both tests were in the same field.

1948 EXPERIMENTS.—Following the promising results obtained in 1947, more inclusive tests were carried on in 1948: one against first generation borer and the other against second generation. The first

Table 2.—Second generation corn borer control on canning sweet corn resulting from two applications of concentrated sprays applied with fan nozzles.[4]

Toxicant	Pounds per Acre	Co-Solvent	Fl. Ounces per 3 Gals.	Base Oil	Gals. per Acre	Borers per 100 Plants	Per Cent Control
DDT	2.00	A	62.08	AA	3[3]	330	71.8
DDT	2.00	C	65.43	BB	3[3]	396	66.1
DDT	1.50	G	37.53	EE	3[2]	522	55.4
DDT	1.00	(2 qts. 25% DDT emul. conc.)			3	528	54.9
DDT	0.50	(1 qt. 25% DDT emul. conc.)			3	595	49.2
DDT	0.60		none	AA	3[1]	630	46.2
DDT	1.00		none	BB	3[1]	665	43.2
DDT	0.60		none	BB	3[1]	673	42.5
Dichlorodiphenyl dichloroethane	1.00		none	BB	3[1]	702	40.1
DDT	0.80		none	BB	4[1]	702	40.1
Ryania (extractives equivalent to 24 lbs. of stems in oil solution)				BB	3[1]	750	36.0
DDT	1.33		none	BB	4[1]	865	26.1
Untreated						1170	0.0
						L.S.D.	217

[1] Slightly phytotoxic.
[2] Moderately phytotoxic.
[3] Highly phytotoxic.
[4] *Teejet 500050.*

of these was a comparison of 25 concentrated sprays with two dilute sprays. The 27 treatments and an untreated check were randomized in three blocks in a field of Marcross sweet corn, which was planted on April 30. Individual plots were four rows wide and 146 feet long. Applications were made June 25, July 2 and 8.

Oviposition was very low during the first generation of the borer in 1948 and the experimental field received only 32 egg masses per 100 plants. However, since borer survival on the Marcross variety was exceptionally high (6.3 borers per egg mass) the borer populations at harvest time were of sufficient magnitude to give significant differences between certain of the treatments.

All but one of the concentrated sprays were applied by means of two nozzles[2] to the row. Each of these nozzles was above the row of corn and slightly off center but adjusted to direct the spray into the whorl of the plants. One concentrated spray was applied with three Teejet 1.27 nozzles per row. One treatment was made with two Teejet 650067 nozzles to the row and at the same pressure as with the concentrated sprays but the sprayer was operated at a slower rate of speed to obtain a 10 gallon per acre application. A 50 gallon per acre application was made with a conventional sprayer at a pressure of 200 pounds. The results of the first 1948 test as shown in table 4, were determined at the time of harvest (12 days after the last application) by dissecting 10 plants per plot.

The second evaluation of concentrated sprays in 1948 was conducted against the second generation corn borer on a late planting of yellow canning corn. The borer population in this test was quite low as was the case in the first generation experiment. Oviposition in the field amounted to 110 masses per 100 plants. Because of the low level of egg deposition, only two applications were made; one on Aug. 19 and the second on Aug. 25. A four replicate randomized block design was used for this experiment. Individual plots were four rows wide and 285 feet long.

All but one of the concentrated sprays were applied with three hollow-cone nozzles[1] to the row. The one exception was a spray applied with two fan-spray nozzles[2] per row which was included for a comparison of nozzles in the application of concentrated sprays on sweet corn in an advanced stage of development. An application of DDT emulsion was made at the rate of 10 gallons per acre through the 1.27 nozzles by decreasing the speed of the spray rig. DDT emulsion was also applied at the rate of 50 gallons to the acre, but in this case a conventional high pressure (200 lbs.) sprayer was employed.

Sixteen days following the last application of insecticides, the resuls of the experiment were determined by examining 30 ears from each plot and counting the number of borers present in the husks or feeding on the kernels. The identification of the various sprays used in this test and the results obtained are given in table 5.

DISCUSSION.—The one experiment conducted against the first generation corn borer (Table 4) seemed to indicate that low quantities of liquid are not as satisfactory for the control of this generation as are higher volume spray applications. These findings might be explained by the fact that application rates as low as 3 gallons to the acre do not provide sufficient liquid to cause immediate penetration into the whorl of the plant where young borers usually abound in the greatest numbers. However, the second generation experiment in 1948 (Table 5) showed that three gallon applications were as effective as 10 and 50 gallon rates. This was particularly true of insecticidal oil solutions.

The application of insecticides for second generation corn borer control on canning corn is usually done at a time when the plants have tasseled and ear development has started. Under such conditions there is no single place to apply sprays that will retain a great amount of liquid. The most favorable location for the spray is on the developing ears and excessive amounts of liquid applied directly to the ears tend only to dilute the amount of insecticide remaining on the husks and flag leaves. An insecticide applied in only 3 gallons of liquid to the acre is not lost by run-off and if such a spray is directed at the ears a greater quantity of the toxicant is likely to remain on the ears. Insecticidal oil solutions applied at the rate of 3 gallons to the acre have the advantage stated above and in addition they may have an added advantage over water

[1] *Teejet 1.27.*
[2] *Teejet 650067.*

Table 4.—First generation corn borer control resulting from the application of concentrated and dilute insecticidal sprays during 1948.

TOXICANT AND POUNDS PER ACRE		CO-SOLVENT	FL. OZ. PER 3 GALS.	BASE OIL	GALS. PER ACRE	BORERS PER 100 PLANTS	PER CENT CONTROL
DDT	1.5	(3 qts. 25% DDT emul. conc.)			50	26.7	86.9
DDT	1.5	(3 qts. 25% DDT emul. conc.)			10	40.0	80.3
DDT	1.5	A	38.34	CC	3[3]	40.0	80.3
DDT	1.5	A	38.34	DD	3[3]	43.3	78.8
DDT	1.5	A	38.34	AA	3[3]	46.7	77.0
DDT	1.5	D	56.81	BB	3[2]	46.7	77.0
DDT	1.5	A	38.34	BB	3[3]	50.0	75.4
DDT	1.5	A	38.34	EE	3[3]	56.7	72.1
Ryania (extractives equivalent to 6 lbs. of stems in water solution)					3	56.7	72.1
DDT	2.0	G	66.85	BB	3[1]	60.0	70.5
DDT	1.5	(3 qts. 25% DDT emul. conc)			3	63.3	68.9
DDT[4]	1.5	A	38.34	BB	3[3]	63.3	68.9
DDT	1.5	H	20.89	BB	3[1]	70.0	65.6
Rotenone	0.08	(derived from 2% rotenone 8% piperonyl butoxide emul. conc.)			3	90.0	55.7
DDT	1.5	G	49.91	BB	3[1]	93.3	54.1
DDT	1.0	none		BB	3[1]	100.0	50.8
Ryania (extractives equivalent to 6 lbs. of stems in water emulsion)					3[3]	103.3	49.2
Parathion	0.5	G	20.29	BB	3[1]	106.7	47.5
DDT plus Chlordane	1.0+0.5	G	38.10	BB	3[2]	113.3	44.3
Toxaphene	2.0	none		BB	3[3]	120.0	41.0
Ryania (extractives equivalent to 16 lbs. of stems in oil solution)				BB	3[2]	126.7	37.7
DDT plus Chlordane	0.5+1.0	G	5.07	BB	3[3]	136.7	32.8
Aldrin	0.5	none		BB	3	136.7	32.8
Toxaphene	1.5	none		BB	3[3]	153.3	24.6
Heptachlor	0.5	none		BB	3	183.3	9.8
UNTREATED	—			—	—	203.3	0.0
Chlordane	1.5	none		BB	3[2]	216.7	0.0
Chlordane	2.0	none		BB	3[3]	209.0	0.0
					L.S.D.	79.0	

[1] Slightly phytotoxic.
[2] Moderately phytotoxic.
[3] Highly phytotoxic.
[4] This treatment was applied with 3 hollow-cone nozzles[1] per row.

solutions or water emulsions in that they enable the toxicant to disperse more evenly over the plant tissue due to the mobility of the oil.

Concentrated sprays of emulsifiable DDT and oil solutions of this insecticide proved to be quite effective against the second generation corn borer if 1.5 to 2.0 pounds of DDT were provided to the acre. Such quantities of DDT could not be held in 3 gallons of oil without the addition of a co-solvent. While there was no significant difference in borer control between the various co-solvents used in DDT oil solutions, the data in tables 2, 4, and 5 all indicate that co-solvent A[2] offered some advantage as measured by corn borer reductions. However, this co-solvent caused rather severe injury to corn foliage when used in quantities sufficient to dissolve the entire amount of DDT in the spray. An attempt was made to reduce this injury by the use of the first treatment in table 5. In this case, only 3.25 ounces of co-solvent A were used in 3 gallons of spray. The base oil (EE) in this formulation was mineral seal oil which will dissolve a relatively large

[1] *Teejet 1.27.*
[2] *Velsicol AR60.*

Table 5.—Second generation corn borer control resulting from the application of concentrated and dilute insecticidal sprays during 1948.

Toxicant and Pounds per Acre		Co. Solvent	Fl. Oz. per 3 Gals.	Base Oil	Gals. per Acre	Borers per 100 Plants	Per Cent Control
DDT	1.5	A	3.25	EE	3[1]	3.3	96.2
DDT	1.5	A	38.34	BB	3[3]	5.0	94.2
DDT	2.0	A	51.13	BB	3[3]	5.0	94.2
DDT	1.5	A	38.34	EE	3[2]	8.3	90.3
Ryania (extractives equivalent to 24 lbs. of stems in oil solution)				BB	3[2]	9.1	89.4
DDT	2.0	(4 qts. 25% DDT emul. conc.)			3	9.1	89.4
Toxaphene	3.0	none		BB	3[3]	12.5	85.4
Parathion	1.0	G	60.86	BB	3[2]	13.3	84.5
DDT	1.5	(3 qts. 25% DDT emul. conc.)			10	15.0	82.5
DDT	1.5	G	49.91	BB	3[1]	15.8	81.6
DDT	1.5	H	20.89	BB	3[1]	15.8	81.6
DDT	1.5	D	56.81	BB	3[1]	16.6	80.7
DDT	1.5	E	40.27	BB	3[1]	16.6	80.7
DDT	1.0	(2 qts. 25% DDT emul. conc.)			3	18.3	78.7
DDT	1.33	none		BB	4[1]	19.1	77.7
DDT	1.5	(3 qts. 25% DDT emul. conc.)			50	20.1	76.7
DDT	1.5	C	52.85	BB	3[2]	20.1	76.7
DDT	1.5	F	56.81	BB	3[3]	20.8	75.8
DDT	1.5	B	38.04	BB	3[1]	22.5	73.8
DDT	1.5	(3 qts. 25% DDT emul. conc.)			3	25.0	70.9
DDT	1.67	none		BB	5[1]	25.8	69.9
Aldrin	1.0	none		BB	3[1]	29.1	66.1
DDT	0.5	(1 qt. 25% DDT emul. conc.)			3	30.8	64.1
DDT[4]	1.0	none		BB	3[1]	34.1	60.2
DDT	1.0	none		BB	3[1]	40.8	52.4
DDT	1.0	A	25.56	BB	3[1]	47.5	44.6
Rotenone plus Pyrethrins	0.04 / 0.008	(derived from 1% rotenone—0.2% pyrethrins—8% piperonyl butoxide emulsion concentrate)			3	54.1	36.9
UNTREATED						85.8	0.0
					L.S.D.	22.6	

[1] Slightly phytotoxic.
[2] Moderately phytotoxic.
[3] Highly phytotoxic.
[4] This treatment was applied with two *Teejet 650067* nozzles per row.

amount of DDT by itself, thus requiring a minimum of co-solvent to maintain the solution at normal summer temperatures. This formulation gave excellent corn borer control and resulted in only slight injury to the plants. The other methylated naphthalene co-solvents (B through F) were approximately equal in their phytotoxicity to corn. Highly volatile carbon tetrachloride (G) and cyclohexanone (H) were the least injurious of the co-solvents. However the high volatility of these solvents made them less satisfactory as DDT co-solvents because of their tendency to dissipate during storage.

The five base oils used in DDT oil sprays did not cause significantly different corn borer reductions when combined with equal amounts of co-solvents A (Table 4). The greater solubility of DDT in mineral seal oil (EE) gave this oil an advantage in that less co-solvent was required to complete the solution. Sprays containing horticultural oil (AA)[1] were difficult to apply during the cool part of the day because of the high viscosity of the oil (130 sec.).

Of the various insecticides included in this study, only parathion showed prom-

[1] *Superla 13.*

ise of being more effective than DDT. The data in Table 5 show that 1 pound of parathion per acre was significantly more effective than 1 pound of DDT when both were applied as oil solutions. Dichlorodiphenyl dichloroethane and aldrin proved to have the same relative toxicity to the corn borer as DDT when applied as concentrated sprays.

Ryania extractives in oil solution, water solution, and as an oil emulsion in water gave very erratic results. Tests reported in tables 2 and 4 showed that extractives equivalent to 24 and 16 pounds of stems in oil solution gave only 36.0 and 37.7 per cent control, respectively. However, in the final test shown in table 5, extractives equivalent to 24 pounds of stems caused an 89.4 per cent reduction. *Ryania* extractives from 6 pounds of stems in water solution and in a water emulsion appeared to be slightly more effective than an oil solution containing extractives from 16 pounds of stems (Table 4).

An emulsion which provided 0.08 pound per acre of rotenone in the presence of piperonyl butoxide gave fair control of the borer (Table 4), but an emulsion which contained half this amount of rotenone plus 0.008 pound of pyrethrins in addition to the piperonyl butoxide was very ineffective (Table 5).

Heptachlor applied at 0.5 pound to the acre in an oil solution did not show appreciable control of the corn borer (Table 4). Toxaphene in oil did not give satisfactory borer control until the dosage rate was raised to 3 pounds to the acre (Tables 4 & 5). Oil solutions of toxaphene were extremely phytotoxic even though no co-solvent was employed in the formulations. Plots treated with chlordane in oil solution actually had more borers per plant than untreated plots (Table 4). This circumstance may have come about as a result of little or no borer control from the chlordane but an appreciable kill of the predators which normally reduce the corn borer population.

The atomizing sprayer showed considerable promise as a means for applying low volume sprays. Although the results with this equipment (Table 3) did not show any true differences between the two spraying pressures and the three rates of application, there was an indication that the pressure combination of 5 lbs. liquid and 9 lbs. air was possibly better than the 3.5 lbs. liquid and 13 lbs. air combination. The former of these two settings produced spray droplets which were slightly larger than the droplets resulting from the latter setting but both sprays were more finely divided than one produced with the nozzles[1] as reported in table 2. The corn borer populations in the atomizing sprayer experiment (Table 3) might be compared with the populations reported in table 2 since both tests were conducted in a field where the egg mass counts showed a very uniform distribution. Where 1.0 and 1.33 pounds of DDT to the acre were applied with the pneumatic nozzles or so-called atomizing machine the population was reduced below 50 borers per 100 plants. The same oil formulation applied to provide 1.0 and 1.33 pounds of DDT to the acre resulted in populations of 665 and 865 borers per 100 plants, respectively, when applied with the compressed air sprayer equipped with ordinary hydraulic type nozzles (Table 2).

The comparison of hollow-cone and fan-spray nozzles in the two 1948 experiments did not show any significant advantage for either type. In the first generation test (Table 4), three hollow-cone nozzles[2] to the row gave 68.9 per cent control while the same oil solution of DDT applied through two fan-spray nozzles[3] to the row gave 75.4 per cent borer reduction. The spray from the hollow-cone nozzles was more finely divided than from the fan-spray nozzles and consequently the spray had a greater tendency to drift when applied over the top of small corn plants. In the second generation test of 1948 (Table 5), all but one of the 3-gallon applications were made with three hollow-cone nozzles[2] to the row because it was felt that the more finely divided spray would give more thorough coverage and yet would not be subject to wind drift when most of the spray was applied to the ear zone of tall plants. However, there did not prove to be any advantage for this type of nozzle since 1 pound of DDT per acre in oil solution gave 52.4 per cent control when applied with hollow-cone while 60.2 per cent control resulted from the use of fan-spray nozzles.

[1] *Teejet 500050.*
[2] *Teejet 1.27.*
[3] *Teejet 650057.*

SUMMARY.—Four corn borer control experiments were conducted on sweet corn during 1947 and 1948 to evaluate concentrated insecticidal spray formulations and methods for applying such sprays with ground equipment.

The concentrated sprays were used in most cases at the rate of three gallons to the acre. Concentrated sprays providing 1.5 pounds of DDT to the acre did not give as good first generation corn borer control as a like amount of DDT in dilute emulsion sprays applied at the rates of 10 and 50 gallons to the acre although statistically there was no real difference between these application rates. Against second generation corn borers, certain formulations of DDT applied as concentrated sprays gave as good borer control as the 10 and 50 gallon application rates.

The concentrated sprays containing DDT were oil solutions and water emulsions. Although there was no significant difference in borer control with DDT oil solutions and water emulsion, the oil solutions seemed to offer a slight advantage. Oil solutions of DDT prepared with five different base oils gave approximately the same borer control. From among nine DDT co-solvents used in oil sprays, *Velsicol AR60* proved to be the most effective from the standpoint of borer control but also the most phytotoxic.

Parathion in oil solution was the only other toxicant found to be more toxic than DDT in concentrated spray form. Oil solutions of dichlorodiphenyl dichloroethane and aldrin were approximately equal to comparable sprays of DDT. Oil solutions of toxaphene, heptachlor and chlordane were decidedly inferior to DDT. *Ryania* extractives in water and oil solutions and as a water emulsion gave very erratic results. Emulsion concentrates of rotenone and rotenone plus pyrethrins, each containing eight per cent piperonyl butoxide, did not give satisfactory corn borer control at the dosage levels tested.

Phytotoxic evaluations showed that emulsions were less injurious to corn foliage than oil solutions. The presence of a co-solvent in an oil spray intensified the injury. Methylated naphthalene cosolvents tended to be more deleterious to the corn than carbon tetrachloride and cyclohexanone.

Limited trials with an experimental hydraulic-pneumatic atomizing sprayer showed that this method of applying concentrated sprays might offer some advantage over a typical hydraulic sprayer for second generation corn borer control. Sprays applied with hollow-cone and fan-spray nozzles gave approximately the same borer control.

LITERATURE CITED

Batchelder, C. H., and D. D. Questel. 1945. Experiment with DDT for the control of the European corn borer infesting sweet corn at Toledo, Ohio in 1944. U.S.D.A., Bur. Ent. Plant. Quar., 659.

Bigger, J. H., G. C. Decker, J. M. Wright, and H. B. Petty. 1947. Insecticides to control the European corn borer in field corn. JOUR. ECON. ENT. **40**(3): 401–7.

Decker, G. C., J. W. Apple, J. M. Wright, and H. B. Petty. 1947. European corn borer control on canning corn. JOUR. ECON. ENT. **40**(3): 395–400.

DR. JAMES G. SANDERS RETIRES

Dr. Sanders, president of the Association in 1922, recently retired as entomologist of the Commercial Solvents Corporation of New York City, a position he held for the past 4 years. Dr. Sanders was one of the pioneers in the development of benzene hexachloride. Recently he was chairman of the BHC Committee of the National Agricultural Chemical Association for three years. He originated the 3-5-40 dust combination now recommended by the United States Department of Agriculture for cotton dusting and also invented and developed *Kwell* ointment, a pharmaceutical product of CSC. Many entomologists who are not too young will remember Dr. Sanders' connection with the United States Bureau of Entomology in 1905, his professorship of entomology at the University of Wisconsin in 1910, his positions as state zoologist and director of the Bureau of Plant Industry in Pennsylvania after 1916 and his early papers on the Coccidae and Cicadellidae, together with his enthusiastic ideas at many past meetings of the Association. Dr. Sanders after a fishing vacation in the North Woods, will live, but not settle down, at 19 Glenwood Drive, Westerville, Ohio.

Stalk Breakage Caused by European Corn Borer and Its Effect on the Harvesting of Field Corn[1,2]

H. C. Chiang and A. C. Hodson, *University of Minnesota*

There are at least four ways in which the European corn borer can damage the corn crop. First, the boring and feeding of the larvae interfere physiologically with plant growth and thus reduce the growth of the ears. Second, their feeding destroys the kernels. Third, their boring in the stalks and ear shanks structurally weakens the plant and causes stalk breakage and ear dropping. And fourth, avenues for the entrance of rots are created (Christensen & Schneider 1950). The relative importance of these types of damage depends upon factors such as the stage of growth at which the plant is attacked, the variety of the corn plants and the farming practice. Thus Thompson (1938) showed that some hybrids showed less breakage than others with the same degree of infestation, while Ficht (1932) found that stalk breakage was higher in thin plantings than in denser ones. It is also general knowledge that kernel damage is much less important in field corn than in sweet corn. The present paper will discuss some other factors affecting the relative importance of the borer injuries on ear growth and on stalk breakage.

The first type of damage mentioned above, the boring and feeding which interfere with plant growth, although inconspicuous, represents an absolute loss which takes place before harvest time. The second type, destruction of kernels, is also irreparable. In sweet corn, this damage is more serious than just the loss of kernels due to direct feeding, because in the canning process, a large portion of the injured ear has to be trimmed off to ensure a complete elimination of contamination. The third type of damage, the weakening of stalks and ear shanks, may be much more conspicuous and alarming than the first type, because a large fraction of the ears will be left unpicked after mechanical picking as a result of stalk breakage. Yet the loss is not complete. Excluding the ears that touch the ground early in the season and become rotted and moldy, usually an insignificant fraction, the ears left unpicked, either on broken stalks or detached and dropped on the ground, can be recovered by hand.

There is much information published on the overall damage done by the corn borer to the corn crop, and also on the effect of borers on ear growth. But the specific quantitative relation between stalk breakage and mechanical picking has not been emphasized. Work along this line was started in 1948. More extensive treatment of the results of the first two types of damage will be presented elsewhere when the studies are completed. The present paper deals mainly with the third type, namely, the relations between stalk breakage and ear dropping and the mechanical picking of field corn, and the effect of planting and harvesting time on these relationships. Since mechanical picking is becoming a very common farm practice, this study assumes an increasingly great importance.

The investigation was carried out at Waseca, Minnesota, in the zone of heavy borer infestation where there are two broods annually. A common variety in that region, Minhybrid 503 was used for this study. The experiments include both quantitative observations on corn damaged by the corn borer and artifical breakage.

The Effect of Artificial Breakage on Ear Growth.—Stalk breakage is a common result of corn borer infestation. It was thought that it might affect ear growth as well as the picking process, although it does not become extensive until the corn plants have reached maturity, even in fields of heavy infestation. To clarify this point experimentally, stalks were artificially broken by cutting half through the stalks and bending them over. Two aspects were studied, namely, the level of breakage and the time of breakage. The first part was done in

[1] Paper No. 2555. Scientific Journal Series. Minnesota Agricultural Experiment Station.

[2] The authors wish to express their appreciation to Mr. R.E. Hodgson, the superintendent of the S. E. Experiment Station University of Minnesota, Waseca, Minnesota, where this work was done, for his fine cooperation and assistance. Thanks are also due to Dr. E. L. Pinnell, Division of Agronomy, University of Minnesota, for his valuable help and to Dr. F. G. Holdaway Division of Entomology and Economic Zoology, for a critical reading of the manuscript.

1948, at the time when the majority of the plants were in the "roasting silk" stage. Stalk breakages were made at seven levels, some below and some above the ear. Eighty-nine plants in the full silk stage and 171 plants in the roasting silk stage were used in the experiments. At the time they were selected they were free from borer, however, some were infested later by second brood borers. This experimental manipulation covered a longer time period than what was needed to stimulate the natural situation. This was done for the purpose of determining the trend of the influence of both time and level of breakage on ear growth. The ears were picked at the ordinary harvest time, and were dried to about a 2 per cent moisture content. The second part was done in 1949. In this case stalk breakage was made at two levels, one immediately above and one immediately below the first ear, at weekly intervals starting from the time of tasselling to the time the plants reached maturity. Fifty plants were used each time for each level. The ears were picked at the ordinary harvest time and weighed. Dry weight and moisture content were obtained from a sample of these ears. The characteristics of the breakage and the resulting ear weight are summarized in tables 1 and 2. From table 1, it is clearly shown that the effect of stalk breakage in reducing ear growth was more severe when the breakage took place at a lower level than at higher levels. Results of a similar trend have been shown by Dibble and Martin (1929). And also at the levels below the ears, the effect of breakage was more severe when the plant was in full silk than in the roasting silk stage. The data in table 2 are the results of a further analysis of the time factor in stalk breakage. Some very interesting relationships were revealed in this study.

With breakage immediately above the first ear the total ear growth (including the first ear and the second ear if present) was reduced more when the breakage took place early than when late, and no reduction was noticeable when the breakage took place as late as one week prior to the date of plant maturity. And the earlier the breakage took place, the fewer plants there were that developed second ears, and the smaller was the percentage of the total ear growth contributed by the second ears. In other words, early breakage suppressed the development of the second ears.

The effects of breakage immediately below the first ears were considerably different from those discussed above. First, the total ear growth did not decrease progressively with early breakage, instead, it was higher for the earliest breakage than in the plants broken two weeks later. Secondly, the percentage of plants having second ears followed the same trend as the total ear growth. And finally, the percentage of total ear growth contributed by the second ears increased with early breakage.

The above relationships show that stalk breakage at a low level on the plants or early in the season has a more severe adverse effect on ear growth than higher or later breakage. Early breakage above the first ear reduced the growth of the

Table 1.—Reduction in ear growth on stalks artificially broken at various levels when the plants were in full silk and roasting stages.

Level of Breakage, No. Nodes from Base	Plants with Full Silk			Plants with Roasting Silk		
	No. of Ears	Average Dry Wt. of Ears (Gms.)	Per Cent Reduction[2]	No. of Ears	Average Dry Wt. of Ears (Gms.)	Per Cent Reduction[2]
8	8	97.8	41.3	21	130.8	31.9
9	11	107.7	35.3	17	136.8	28.8
10[1]	10	126.8	23.8	22	143.8	25.1
11	12	118.8	28.6	22	139.7	27.3
13	13	144.6	13.2	22	169.7	11.6
15	12	155.4	6.0	22	172.7	9.6
Tassel	12	154.9	7.0	23	169.0	11.9
Check	11	166.5		22	192.0	

[1] Average level of the first ear.
[2] Relative to ear weight of check.

Table 2.—The effect on ear growth of artificial stalk breakage above and below the first ears at weekly intervals after tasseling.

No. of Weeks After Tasseling When Stalks Were Broken	Total Ear Growth per Plant (Dry Wt. in Grms.)	Per Cent Contributed by First Ears	Per Cent Contributed by Second Ears	Per Cent of Plants with First Ears	Per Cent of Plants with Second Ears
		Breaking above 1st Ears			
1	86.2	100	0	100	0
2	100.7	100	0	100	0
3	88.2	99.1	0.9	100	2.2
4	151.2	96.1	3.9	100	1.1
5	158.2	91.0	9.0	100	30.0
6	195.7	83.1	16.9	100	26.0
		Breaking below 1st Ears			
1	80.9	21.6	78.4	32	88
2	59.9	20.1	79.9	28	66
3	46.7	84.6	15.4	100	14.3
4	110.2	60.0	40.0	100	60.4
5	105.6	75.8	24.2	100	34.6
6	154.9	80.9	19.1	100	52.1
		Check			
	190.9	83.8	16.2	100	26.0

first ear and also suppressed the growth of the second ear and thus reduced the total ear growth. Breakage below the first ear stopped the further growth of the first ear. But when it took place early enough, the second ear developed more than otherwise and thus raised the total ear growth of the plant. In the case of mid-season breakage, the low ear growth was a result of the fact that the first ears were prevented from further growth and at the same time the plants were too old to promote the growth of second ears. Therefore the ear growth was greater when the breakage took place either early or late than when breakage took place in mid-season.

THE EFFECT OF CORN BORER POPULATIONS ON STALK BREAKAGE AND EAR DROPPING.—The stalk breakage as well as ear dropping may be considered a function of the population level and the particular brood of the attacking borer. An investigation to determine the nature of this relationship was made over the same two-year period as that in which the level and time of artificial breakage was studied. There was one planting under observation in 1948 and two plantings in 1949. The borer infestation in 1948 was generally low, and the two plantings in 1949 were infested at different levels by the first and the second brood larvae because of differences in planting dates. It is possible to present the relationship between borer infestation and stalk breakage over a fairly wide range of infestation levels by combining the results from the two-years' observations. The infestation of the 1948 planting was observed on 400 plants and that of the two 1949 plantings on 90 plants each. Table 3 shows the infestation from both broods and the percentages of stalk breakage and ear dropping which were checked about one month after the corn reached maturity.

These data show that the infestation level in 1949 was generally higher than that of 1948 and that in 1949 the early planting received more egg masses from the first brood and less from the second brood than the late planting. It is also clear that in the three plantings under observation, the percentage of stalks broken above the ear followed the trend of first brood infestation and that similar figures for breakage below the ear followed the trend of second brood infestation as did the percentage of ear dropping. These facts suggest that the first brood larvae caused stalk breakage above the ears and that stalk breakage below the ear and ear dropping were caused principally by second brood larvae.

THE SEASONAL OCCURRENCE OF STALK BREAKAGE AND EAR DROPPING.—From

the observations made in 1948, it was noticed that stalk breakage and ear dropping did not start until late in the season. More systematic observations were carried on in 1949. Three rows were designated for this purpose for each of the two plantings (early and late). Stalk breakage and ear dropping were checked once a week during the growing season and a few times after the corn plants reached maturity. The percentage of stalks broken both above and below the ear and the percentage of dropped ears present at various times are presented in table 4.

The records taken on October 17 probably show an exaggerated amount of breakage and ear dropping because a wind which reached a velocity of about 90 miles per hour damaged corn fields on October 10, 1949. However, up to the last check (Sept. 29) before the big winds, the breakage below the ears had already shown a higher percentage in the late planting than in the early planting. Of greatest significance is the fact that the stalk breakage, high and low, amounted to only an insignificant fraction before the corn plants reached maturity (about Sept. 3), that ear dropping became significant even later; and further that both stalk breakage and ear dropping increased rapidly after the corn plants started to dry out. These manifestations of structural damage are shown to be a function of time and the seasonal change in plant condition. The apparent decrease in high breakage late in the season is due to the fact that plants broken above the ear were recorded among those with low breakage if this occurred subsequently on the same plant.

Table 3.—The infestation level of first and second brood borers as related to stalk breakage in early and late plantings.

Planting	1948,	1949, Early	1949, Late
Planting Date	5/15	5/3	5/17
Maturity Date	9/24	8/27	9/2
Infestation Level (No. Egg Masses per 100 Plants) First Brood	27.2	174.4	58.8
2nd Brood	45.9	216.6	490.0
Stalk Breakage and Ear Dropping No. Stalks examined	750	1036	1850
Time (in Days after Corn Maturity) when the Examinations were made	33	33	27
Per Cent Stalks Broken above the Ears	13.6	40.1	29.1
Per Cent Stalks Broken below the Ears	10.1	21.0	43.4
Total Per Cent Stalk Breakage	23.7	61.1	72.5
Per Cent Ears Dropped	2.5	6.3	26.3

CHARACTERISTICS OF BREAKAGE IN RELATION TO THE EFFICIENCY OF MECHANICAL CORN PICKER.—In order to study the exact effect of stalk breakage on the mechanical picking process, stalks in parts of the field were artificially broken at various levels and bent over in various directions and were tagged accordingly before the mechanical picker went through the field. The ears left on both broken stalks and standing stalks

Table 4.—Seasonal increase in breakage and ear dropping.

	Early Planting				Late Planting			
Date	Total No. Stalks Observed	Per Cent Stalks Broken Above Ears	Per Cent Stalks Broken Below Ears	Per Cent Ears Dropped	Total No. Stalks Observed	Per Cent Stalks Broken Above Ears	Per Cent Stalks Broken Below Ears	Per Cent Ears Dropped
7/12	1044	0	0	0	1921	0	0	0
7/18	1018	0	0	0	1828	0.1	0	0
7/28	997	0.6	0	0	1860	0.1	0	0
8/6	1036	0.5	0	0	1850	0.1	0	0
8/21	1036	0.6	0	0	1850	0.1	0.2	0
8/26	1036	1.6	1.0	0.1	1850	0.5	0.9	0
9/3[1]	1036	12.7	1.0	0.1	1850	23.4	3.5	0
9/10	1036	35.9	2.4	0.1	1850	44.3	5.8	0
9/23	1036	47.9	19.1	3.7	1850	39.4	26.3	11.4
9/29	1036	40.1	21.0	6.3	1850	29.1	43.4	26.3
10/17	1010	7.9	59.4	32.7	1841	1.0	45.5	32.3

[1] Corn reached maturity.

were counted after the picking. This study was carried on in 1948 at the usual harvest time. A two-row picker[1] was used and it was operated with a tractor.[2] The results are shown in table 5.

Several points are clarified by this experiment. The mechanical picker used was very efficient in picking ears from normal standing stalks as no ears were missed on such stalks. Neither were ears missed in picking stalks broken above the ears. So it is apparent that stalk breakage above the ears had little effect on the efficiency of harvesting. However, some ears on stalks broken near the ground were missed. In such cases, the efficiency depended upon the direction in which the stalks were bent or broken. Picking efficiency was least affected when the stalks lay across the line of operation, most affected when the stalks lay in the direction of picking, and intermediate when they were directed against the movement of the mechanical picker.

THE EFFECT OF TIME OF PICKING ON THE EFFICIENCY OF PICKING THE EARS FROM BROKEN STALKS AND ON HARVEST LOSS.—It was made clear that even in a rather heavily infested field, only a small fraction of the corn stalks were broken below the ears and that practically no ears dropped before the corn reached maturity, and further, that both stalk breakages and ear dropping increased rapidly after the corn plants started to dry out. From these facts, it would seem likely that when picking at a later season one would encounter a higher stalk breakage and ear dropping, with a heavier crop loss than if picking were done at an earlier time. In order to quantitatively determine the relative loss due to the factors of stalk breakage and ear dropping at different times, six rows were picked soon after the time when the corn was safe for cribbing, and six other rows about four weeks later. These rows were set aside at the beginning of the season for this use and had not been disturbed until picking time. Before each picking, counts were made of the ears on standing stalks, on stalks broken below the ears, and on stalks broken close to the ground and also of the detached ears on the ground. Since it had been found that the ears on stalks broken above the ears had the same picking quality as those on standing stalks, stalks with no breakage below the ears were all classified as standing stalks. The ears in each category were painted with a different color. After the picker went through the field, the ears left in the field were checked. According to the color marking, it was possible to determine the original status of these unpicked ears. The records on the field conditions at picking time are shown in section I, table 6. It is shown that at the same picking time, the percentage of stalk breakage and ear dropping were consistently lower in the early planting than in the late planting, and for the same planting, they were consistently lower at the first picking than at the second picking.

Table 5.—The efficiency of harvesting corn from broken stalks with a mechanical corn picker.

SERIES[1]	NO. OF REPLICATIONS	TOTAL NO. OF PLANTS	NO. OF EARS MISSED IN PICKING	PER CENT OF EARS MISSING
A	3	149	0	0
B	1	49	26	53.1
C	2	100	20	20.0
D	3	149	14	9.4
E	3	148	0	0

[1] A. Stalks broken on the internode below the ear.
B. Stalk broken on the internode above the ground with stalks running in the rows in the direction of the picking operation.
C. Stalk broken on the internode above the ground with stalks running in the row but against the direction of the picking operation.
D. Stalk broken on the internode above the ground and with stalks running across the rows.
E. Check series, standing stalks.

The picking quality of the ears on stalks of different status, as represented by the per cent of ears picked up, is presented in section II of table 6. It is shown that practically all the ears on standing stalks were harvested, and practically all the ears on the ground were left unpicked. However, a varied percentage of the ears on broken stalks were left in the field. This percentage was higher for stalks broken low than for those broken at higher levels. More interesting is the fact that even with stalks broken at the same level, the picking efficiency of the ears was lower at the second picking than at the first. This was true for both plantings. This change may be explained by the fact that the ear shanks and the breakage points on the

[1] McCormick Deering 2-M.
[2] M Cormick Deering Farmall 1-M.

Table 6.—Breakage and picking quality in relation to harvest loss as affected by planting date and picking time.

PLANTING	1949, EARLY		1949, LATE	
PICKING DATE	9/28	10/22	9/28	10/22
TOTAL NO. STALKS OBSERVED	1864	1821	2856	3189
I. Field conditions at picking time				
Per cent of stalks broken near ground	6.1	15.5	20.9	8.9
Per cent of stalks broken below ears	11.4	56.1	22.1	55.3
Per cent ears dropped	9.9	23.9	19.7	34.4
Per cent stalks standing with ears	72.6	4.5	37.3	1.4
II. Per cent of ears picked up from stalks of various states				
Stalks broken near ground	68.4	45.7	76.3	52.5
Stalks broken below ears	84.0	58.9	71.2	59.5
Ears dropped	11.0	5.5	13.5	1.4
Standing stalks	97.4	96.3	98.0	100
III. Per cent of ears left unpicked due to various causes				
Breakage near ground	1.9	8.4	5.0	4.2
Breakage below ears	1.8	23.1	6.4	22.5
Ear droppage	8.8	22.6	17.0	33.7
Standing stalks	1.9	0.2	0.7	0
Unidentified	2.4	0.6	3.6	0.4
Total per cent of ears left unpicked	16.8	54.9	32.7	60.8

stalks were more fragile after a longer period of weathering. If this was the case, those parts of the stalks and ears that were broken but still attached to the main stalks, would be more likely to be broken off before they reached the snapping rollers of the picking machine. This explanation is in accordance with the findings of Smith *et al.* (1949). These authors reported that the percentage of ear dropping during mechanical picking increased with the degree of drying. Under normal field condition, they found that late picking increased the picking loss where borer damage was not involved.

Due to the combined effects of the increasing breakage and ear dropping and the decreasing picking quality of the ears on broken stalks, the harvest loss from the first picking and that from the second picking showed an astonishing difference. This point is shown in section III of table 6. It was unfortunate that strong winds occurred a short time before the second picking and probably exaggerated the magnitude of the differences observed. However, similar differences were found for the 1948 crop. In 1948 the probable harvest waste at the time of corn maturity was calculated on the basis of the expected reduction in picking efficiency due to breakage and ear dropping then known to exist. These data were compared with actual harvest records taken one month later after considerable weathering had taken place. In this case the loss, if the corn were picked at maturity, would have been about 14 per cent of that obtained one month later. Although, in practice, corn would not be picked at maturity this comparison shows further that picking efficiency would be expected to decrease with time.

Since there are changes in moisture content following corn maturity it is important to know how early corn can be harvested and still be safe for cribbing, To determine this point, the moisture

Table 7.—The dry weight and moisture content of ears at various times.

PLANTING	1949, EARLY	1949, LATE
Average dry Weight of Ears (in gms.)		
At maturity (Sept. 1–5)	137.4	154.9
At first picking (Sept. 29)	124.1	162.9
At second picking (Oct. 17)	121.0	153.3
Moisture Content (% of green weight)		
At maturity (Sept. 1–5)	46.2	42.9
At first picking (Sept. 29)	17.2	—
At second picking (Oct. 17)	13.9	12.9

content of ears was determined at the time of both the early and late picking. The results are shown in table 7. It is clear that the dry weight of ears showed no noticeable increase from the time of corn maturity to a time about seven weeks later: moisture content, however, showed a considerable drop during the first month after corn maturity and varied only very slightly thereafter. It is evident then, that a late picking results in a little gain in ear drying and no gain in ear size, while the harvest loss may be doubled by delaying harvesting.

LOSSES DUE TO THE REDUCTION IN EAR GROWTH COMPARED WITH WASTE AT HARVEST TIME.—As was pointed out in the introduction, the borer reduces ear growth as well as causing stalk breakage and ear dropping. Although a complete analysis of the effect of borer damage on ear growth will be published elsewhere, a brief comparison of the loss due to these two types of injury is pertinent.

Samples of ears from each planting were picked, dried and weighed. The average ear weights were converted into yield expressed in the number of bushels per acre. Such figures represent the yield after the borers have exerted their effect on ear growth. To obtain the exact amount of reduction in ear growth, it is necessary to compare the yield of infested plants with uninfested ones. Unfortunately, no plants in either planting were free from borer infestation in 1949. So the yield calculated from the average weight of the ears from clean stalks in 1948 was used as the normal yield. It is realized that this could be different from that of the 1949 plantings, yet it was the closest figure we had, and is good enough for a rough comparison. Losses of both types, ear growth reduction and harvest waste, are summarized in table 8.

From these data, it is to be noted that the loss in yield before harvesting, due to the reduction in ear growth, was about twice as great in the early planting as in the late planting. At the first picking, the loss due to the reduction in ear growth was greater than the harvest waste in the early planting, and the reverse was true for the late planting. At the second picking, however, the loss due to harvest waste exceeded that due to the reduction in ear growth in both plantings. The last two lines in table 8 show the net yield at the two pickings from both plantings. These figures were obtained by subtracting the number of bushels lost during the harvest from the total number of bushels grown on an acre. These yields for early and late plantings picked either early or late came out amazingly close. While under other circumstances such close agreement of the figures would not be expected, the results indicate that with this particular proportion of first and second brood larvae in the field, and with the planting dates chosen, the advantage gained by planting late enough to escape heavy first brood infestation was balanced by a greater harvest waste caused principally by second brood larvae.

SUMMARY AND CONCLUSIONS.—Although stalk breakage affects corn ear growth in a varied manner, depending upon the time when breakage takes place and the position of the break, under field conditions, it usually occurred so late in the season that its effect on ear growth was insignificant. Even with a fairly heavy infestation, stalk breakage before plant maturity was insignificant. However, the incidence of stalk breakage increased rapidly after the plants started to dry out. Also, the rate of increase varied with planting dates and with the corresponding levels of infestation.

Stalk breakage above the ears had little effect on picking efficiency, while below the ears, the lower the breaking point, the poorer was the chance that the ear would be picked from broken stalks by a mechanical picker.

In field tests, it was found that the picking quality of ears on broken stalks decreased as the season advanced. Because of this decrease in picking quality of the

Table 8.—Reduction in ear growth and harvest waste in relation to planting and picking time.

PLANTING	1949, EARLY	1949, LATE
Average dry weight of ears in grams	127.5	157.1
Yield converted (in bushels per acre, 14% moisture)	56.6	69.8
Reduction in yield (in bushels per acre, based on the yield of clean plants in 1948)	25.7	12.5
Per cent reduction in yield due to reduced ear growth	32.5	15.2
Per cent harvest waste, early picking	16.8	32.7
Per cent harvest waste, late picking	54.9	60.8
Harvest waste per acre, early picking	9.5	22.8
Harvest waste per acre, late picking	31.1	42.4
Net yield (Calculated), early picking (bushels per acre)	47.1	47.0
Net yield (Calculated), late picking (bushels per acre)	25.5	25.4

ears on broken stalks, and because of the higher percentage of broken stalks and dropped ears found late in the season, the harvest loss on a late picking date was about twice as great as that of an early picking. Nevertheless ear weight showed no noticeable increase from the time of corn maturity to the time of the second picking, and the moisture content changed very little from the date of the first to that of the second picking. Therefore, shocking, or picking the corn at the earliest possible date safe for cribbing seems advisable if one wishes to reduce the harvest loss and the labor cost of gleaning.

It was also found, in this study, that the net yield for both early and late planting was not significantly different. In other words, although the late planting yielded more as a result of lighter first brood injury, it showed a greater harvest waste. This loss can reach alarming proportions, but much can be recovered by gleaning or by turning livestock into the field. It seems reasonable to conclude that early planting suffers greater permanent damage and that late planting results in heavier recoverable losses. Under circumstances where a light second brood infestation can be expected or where gleaning is profitable, late planting would be preferable if and when the length of the growing season permits.

LITERATURE CITED

Christensen, J. J., and C. L. Schneider. 1950. European corn borer (*Pyrausta nubilalis* Hbn.) in relation to shank, stalk, and ear rots of corn. Phytopath. **40:** 284–91.

Dibble, C. B., and A. P. Martin. 1929. Topping corn does not control corn borer. Mich. Agr. Expt. Sta. Quarterly Bull. **11:** 195–7.

Felt, E. P., and S. W. Bromley. 1931. Developing resistance or tolerance to insect attack. JOUR. ECON. ENT. **24:** 437–43.

Ficht, G. A. 1932. Some studies on the planting rate of corn in relation to oviposition, population and injury by the European corn borer. JOUR. ECON. ENT. **25:** 878–84.

Smith, C. W., W. E. Lyness and T. A. Kiesselbach. 1949. Factors affecting the efficiency of the mechanical corn picker. Neb. Agr. Expt. Sta. Bul. No. 394. 32 pp.

Thompson, R. W. 1938. Further notes on corn borer resistance in hybrid corn; with a brief statement of the infestation situation in Ontario in 1938. 69th Ann. Rep. Ent. Soc. Ont. 1938: 76–81.

Status of European Corn Borer Parasites in the United States

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The last review of the status of European corn borer, *Pyrausta nubilalis* (Hbn.), parasites in the United States was published in 1936 (Baker & Bradley 1936). Since then processed reports of current recoveries have been issued by the Bureau annually as Insect Pest Survey Supplements or as E-series papers. A comprehensive review of colonizations, recoveries, and biological information through 1940 is in process of publication by the U. S. Department of Agriculture (Baker *et al.* 1949).

The information accumulated through 1947 especially that since 1944, is reviewed here to provide a general picture of the results obtained in this phase of biological control of the pest.

Colonization after 1936 was limited almost entirely to those exotic species which had become established in the United States from earlier importations. Adult parasites, for colonization in areas where they were not present, were reared from borers collected in localities having the highest parasite concentrations, and were also obtained from laboratory breeding programs.

With the spread of the borer westward across the most important corn-growing areas, and with greatly increased cooperation by several State agencies, a much expanded colonization program was begun in 1944. State agencies made extensive corn borer collections to determine the extent of establishment, maintenance, and

[1] The author acknowledges the important contribution to the project made by D. W. Jones, S. W. Carter, and other staff members at the Bureau's Moorestown, N. J., laboratory, who have handled nearly all of the rearings for colonization and records of recovery since 1943.

dispersion of the parasites. Most of these collections, together with large numbers made by Bureau personnel, were reared at the Bureau's Moorestown, N. J., laboratory by the individual isolation method to provide parasite data.

Three methods were used in taking samples of borers from the field. (1) Collections to obtain information on initial establishment and maintenance of parasites at colony sites usually consisted of 50 to 100 borers from the immediate vicinity of the release point. (2) Parasite spread and changes in the percentages of borers attacked by them in special study localities were studied by collections, each usually consisting of 50 borers, taken at random from areas of approximately equal size, uniformly spaced around the colonization site. (3) In the Eastern States, where information obtained from the first two sampling methods showed that extensive dispersion of parasites had taken place, a section random method, in which a collection of about 50 borers was taken from each 10 mile square section, was employed over a considerable area without regard to colonization sites. The last method provided information on dispersion and abundance of parasites over extensive areas in 1947.

The information obtained from these three methods of sampling is summarized for each of the six exotic species to show (1) localities and areas where parasites have given evidence of initial establishment but are not known to have survived; (2) where they have survived for one or more years after colonization but are not known to have become a permanent part of the environmental complex; and (3) where, as indicated by available information, they have persisted and are a factor in the environment affecting the host.

Lydella stabulans grisescens R.D.—This larvaevorid is widely distributed in the Eastern States, having spread to many localities where it was never colonized. In Massachusetts, Rhode Island, and Connecticut, and in the Hudson River Valley of New York it is widely distributed but parasitizes only a small percentage of the borers. *L. grisescens* has survived in western New York. It was present throughout an area of approximately 22,000 square miles (Fig. 1) in the Middle Atlantic States, including all of New Jersey and Delaware, and extensive areas in Pennsylvania, Maryland, Virginia, and North Carolina surveyed in the fall of 1947. Of 215 samples taken in the area, *L. grisescens* appeared in 88 per cent, and had parasitized 13 per cent, of the 9468 borers observed.

Lydella stabulans grisescens was colonized and established prior to 1936 in the Lake States area, and has persisted in three localities. In Monroe County, Mich., and Erie and Lucas Counties, Ohio, it annually parasitizes from 10 to 30 per cent of the borers. One specimen of *L. grisescens* was recovered in the spring of 1948 from Ingham County, Mich., where it was never colonized. It has been colonized extensively in nine North Central States since 1944 and has been recovered from all of them. These recoveries are classified into three categories as shown in figure 1. Where the records showed dispersion from the release site, or relatively high rates of parasitization, or both, they were classified as persistent. In 1947 parasitization that fell in that category ranged from 17 to 56 per cent in the nine Illinois localities, and 13 and 30 per cent in the two Indiana counties.

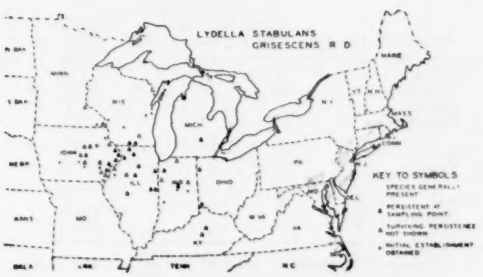

FIG. 1.—Field status of *Lydella stabulans grisescens*, fall of 1947.

Parasitization in 1947 in three Iowa localities, where the parasite had been released, ranged from 15 to 41 per cent. As high as 15 per cent of the borers were attacked in three localities where *Lydella stabulans grisescens* was never released, although it was colonized at other sites in the same counties. This parasite has dispersed rapidly in the central bluegrass area of Kentucky, where it parasitized over 40 per cent of the borers observed in 1947. *L. grisescens* has dispersed widely from the colonization site in southwestern

Ohio (Hamilton County) and in 1947 it parasitized over 30 per cent of the borers observed in that locality. Two counties in southern Wisconsin fall into the class of localities where this parasite is persisting, but parasitization by it has not reached 10 per cent. In one of these localities this species was never colonized, and in the other it has persisted since colonization in 1944.

Most of the localities where *Lydella stabulans grisescens* is classified as surviving are those where sufficient time has not elapsed since colonization, or where observations have not been extensive enough to determine its response to the environment. These localities in Wisconsin, Minnesota, Iowa, Illinois, Indiana, Ohio, and Kentucky form an irregular, interrupted area around or between the areas where the species has persisted, as shown in figure 1. Initial establishment, also shown in figure 1, was found mostly outside the two areas just described. These records are from localities recently colonized, where no data on survival have been obtained.

Table 1.—Annual recoveries of *Horogenes punctorius* (Roman) in north central United States from 1943 through 1947.

State and County	Percentages of Borers Parasitized[1]				
	1943	1944	1945	1946	1947
Illinois					
Rock Island			Tr*	0	0
LaSalle					1*
Vermilion	*	*		9*	0
Indiana					
Tipton	1*	0	0	0	0
Iowa					
Benton				8*	—
Cedar		Tr*	0*	0	—
Clinton					
Comanche Township		1*	0	0	1
Eden Township			3*	0	—
Dubuque				0*	1
Jackson				♀	—
Jones		Tr*	0*	Tr	—
Muscatine		0*	Tr*	0*	0
Kentucky					
Fayette		*	0	Tr*	0
Minnesota					
Fillmore				1*	0
Goodhue				♀*	0
LaSueur				0*	3*
Ohio					
Van Wert				0*	5
Wisconsin					
Dane				1*	—
Door			0*	5*	
Jefferson		0*	0	8*	—
LaCrosse					♀*
Rock					4*

[1] Tr = trace; asterisk = liberation made; 0 = collection of host but no recovery of parasite; dash = no collection of host.

Horogenes punctorius (Roman).—This ichneumonid, found widely distributed in southern New England for several years, was present in the fall of 1947 throughout the surveyed area in Massachusetts except the southeastern part. It was prevalent in the Connecticut River Valley of Connecticut and in one of 11 collections from Rhode Island. It was found quite widely distributed in central and northeastern New Jersey, where it was not colonized during 1947. These areas in New Jersey and one locality in western New York are the only places where this species is known to have persisted. It was recovered from one locality in Rockingham County, N.H., in the fall of 1941, where it was colonized in 1937, but no collection has been made there since. One recovery was made on the Eastern Shore of Maryland in 1947.

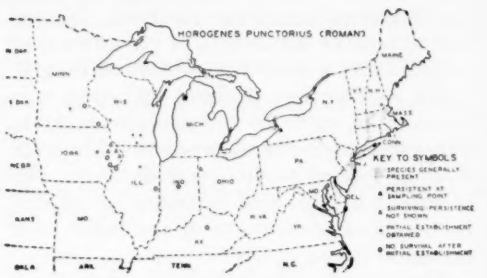

FIG. 2.—Field status of *Horogenes punctorius*, fall of 1947.

Horogenes punctorius was colonized and recovered before 1938 in Steuben County, Ind., Lapeer, Monroe, and St. Clair Counties, Mich., and Hancock, Henry, Lucas, Marion, Putnam, and Wood Counties, Ohio, but apparently has not persisted in any of them. The last recovery from these counties was made in Monroe County in 1937.

Since 1944 *Horogenes punctorius* has been extensively colonized in the North Central States. Although numerous recoveries have been made, as shown in table 1, none has indicated that the species will persist. The most promising results were obtained in Clinton, Dubuque, Jackson, and Jones Counties, Iowa, and in Van Wert County, Ohio, where the parasite survived for one to three years after colonization. The four Iowa localities are in adjacent counties in the eastern part of the State. There were two localities in each of the States of Minnesota, Iowa, and Illinois, one in

central Indiana and one in Kentucky where it has not been recovered following initial establishment. Recoveries showed initial establishment in Benton County, Iowa and Dane, Door, and Jefferson Counties, Wis., in 1946, but these localities were not surveyed in 1947. Recoveries in Fillmore County, Minn., and LaSalle County, Ill., were made in 1947 following colonization that year. The status of *H. punctorius* is shown in figure 2.

Phaeogenes nigridens Wesm.—The ichneumonid *Phaeogenes nigridens* Wesm. is the only exotic parasite established in the United States that attacks the pupa of the host. *P. nigridens* was first colonized in eastern Massachusetts in 1924, and it has persisted there since the first recovery in 1928. It was numerous enough there in 1945 to provide 500 adults for colonization in one locality in Iowa. Attempts to obtain specimens from Massachusetts for additional colonies in 1946 and 1947 were unsuccessful because of the scarcity of the parasite. No observations were made in 1948. No observations were made in Iowa in 1945 and 1946. The parasite was not recovered in 1947 and 1948 from host pupae collected where it had been released.

Macrocentrus gifuensis Ashm.—This polyembryonic braconid was the most widely distributed and most numerous parasite in southern New England in 1947 where, except in central Massachusetts, it parasitized as many as 20 per cent of the borers in 1945, 1946, and 1947. It was found throughout the surveyed area in the Hudson River Valley of New York in 1947, in northeastern

FIG. 3.—Field Status of *Macrocentrus gifuensis*, fall of 1947.

and central New Jersey, and in the vicinity of Philadelphia in southeastern Pennsylvania, as shown in figure 3. It

Table 2.—Annual recoveries of *Macrocentrus gifuensis* Ashm. in the North Central States from 1944 through 1947.

STATE AND COUNTY	PERCENTAGES OF BORERS PARASITIZED[1]			
	1944	1945	1946	1947
ILLINOIS				
LaSalle			2	0
Ogle			1	0
Stephenson			1	0
IOWA				
Black Hawk			3*	—
Cedar	2*	—*	0	—
Clayton			0*	4*
Delaware			2*	—*
Dubuque			4*	0*
Jackson		*	0*	2
Jones	3*	0	0	—
Linn	—*	—*	2*	—
Mitchell				3*
Muscatine	1*	0	Tr*	0
Poweshiek			22*	—
KENTUCKY				
Fayette	2	0	0	0
MINNESOTA				
LeSueur			0*	3*
OHIO				
Hamilton	Tr	0	0	0
Van Wert			*	Tr*
WISCONSIN				
Brown	1*	—	—*	—
Buffalo	—	—	—	5*
Calumet	5*	0	0*	0
Dane	0	0	1*	—
Door		0*	2*	—
Fond du Lac	1*	—	1*	0
Green				1*
Jefferson	6*	0	2*	—
Kenosha	—	Tr*	—	—
LaCrosse	—	—	—	3*
Lafayette	—	—	1*	—
Ozaukee	Tr*	0	0*	—
Rock	0	0	5*	0

[1] Tr = trace; asterisk = liberation made; 0 = collection of host but no recovery of parasite; dash = no collection of host.

was also recovered in Pennsylvania, in at least one year following colonization, from one locality in each of two counties, Montgomery and York, in 1947, and in Chester County in 1946. Recoveries in the fall of 1947 from northern Delaware, and northeastern and western Maryland indicate that it survived there.

Macrocentrus gifuensis was colonized extensively throughout the North Central States each year from 1944 to 1947, inclusive. Annual recoveries are shown in table 2. No collection was made subsequent to initial establishment in Black Hawk, Delaware, Linn, and Poweshiek Counties, Iowa, and Brown, Dane Door, Jefferson, Kenosha, and Lafayette Counties, Wis. The only locality where it has shown survival in a year when it was not colonized was in Jackson County, Iowa in 1947. Here it was released in 1946 but not recovered. Initial establishment was noted in 13 localities in the North Central States, including three in northern Illinois, four in eastern Iowa,

one each in Kentucky and Ohio, and four in Wisconsin. At two localities in the Middle Atlantic States, Sussex County in southern Delaware and Cape May County in southern New Jersey, it showed initial establishment in 1946 when it was colonized, but it was not found in 1947.

Chelonus annulipes Wesm.—The braconid *Chelonus annulipes* was released in single colonies throughout the Eastern and Lake States but less extensively than *Macrocentrus gifuensis*, *Horogenes punctorius*, or *Lydella stabulans grisescens*, especially in the more recently infested states. *C. annulipes* was also liberated in closely spaced, grouped colonies throughout the Lower Connecticut River Valley and the Lower Hudson River Valley.

The species has persisted for several years in three areas in four eastern states, including southeastern Massachusetts and adjoining parts of Rhode Island, the Connecticut River Valley of central Connecticut, and the Hudson River Valley of New York. In these states, as in Italy, the source of importations, it appears to be restricted to limited areas.

It was recovered following initial establishment in Burlington, Gloucester, Middlesex, and Monmouth Counties, N. J., but the last recovery was made in 1945 and the available information indicates that it has not persisted in the state. A recovery was made in 1947 in northern Delaware where it was last released in 1945.

The last recovery of *Chelonus annulipes* in any North Central state was in Lucas County, Ohio, in 1945. Initial establishment was obtained in 1944 in Rock Island County, Ill., Clinton County, Iowa, and Ozaukee County, Wis., but it was not recovered in 1945, 1946, and 1947.

Eulophus viridulus Thoms.—This chalcid, colonized extensively where the corn borer was abundant from 1930 through 1934 and annually in the more recently infested area since 1945, is the only ectoparasite among the exotic species known to be established in the United States. Another distinction of this parasite is that it is the only one known to attack native hosts. It has been taken on *Pyrausta ainsliei* and *P. penitalis* in smartweed. Adult females paralyze the host larvae by stinging them, and then deposit eggs externally on them. The parasite larvae remain outside the host. *E. viridulus* overwinters as a naked pupa in the host burrow. The effectiveness of this species cannot be evaluated by the annual fall survey to determine parasitization, since only those individuals that are present at that time may be observed, whereas it attacks the host throughout the season. Pupae are often found at some distance from the host remains in the burrow, and consequently may not be recognized as parasites by the collector.

The first record of recovery was in Ohio, near the western end of Lake Erie, in 1938 following colonization in 1931 and 1932. It has appeared in collections in that vicinity annually since 1938. It was recovered from four counties in Illinois, two in Indiana, two in Wisconsin, and one in Ohio during 1945, 1946, and 1947, in which counties it was never released. It was not, however, recovered from localities where it had been released. The pattern of these recoveries illustrates the outstanding characteristics of this species—dispersing to great distances from release points, and failing to concentrate at any one point. The easternmost recovery was made in the Cattaraugus Indian Reservation in Western New York, where it was found in 1946 and 1947, after having been colonized in 1931.

Native Parasites.—Three native parasites, *Bassus agilis* (Cress.), *Aplomya caesar* (Ald.), and *Pyraustomyia penitalis* (Coq.), have been reared from the corn borer quite frequently during the past four years. *P. penitalis* was taken from the greatest number of localities, but *B. agilis* and *A. caesar* have been more prevalent in New England, New York, and northern New Jersey. All native parasites combined accounted for only a fraction of one per cent of the borers observed.

LITERATURE CITED

Baker, W. A., and Wm. G. Bradley. 1936. Field status of European corn borer parasites at the close of 1946. JOUR. ECON. ENT. 31(3): 345–8.

Baker, W. A., Wm. G. Bradley, and C. A. Clark. 1949. Biological control of the European corn borer in the United States. U. S. Dept. Agr. Tech. Bul. 983.

Effect of Soil Fertility on Corn Earworm Damage

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Changes in soil fertility often have altered the susceptibility of crops to insect attack. In some cases, as with thrips on spinach (Wittwer & Haseman 1946), increased nitrogen fertilizer reduced the insect injury. With other crops and other insects, an increase in fertilizer resulted in increased insect injury. Such an effect was noted in the case of chinch bugs on sorghum (Dahms and Fenton 1940, and Dahms 1947, cotton aphids on cotton (McGarr 1943), cabbage aphids on cabbage (Evans 1938), and two-spotted mites on beans (Garman & Kennedy 1949). Haseman (1946) discussed the general aspects of the influence of soil fertility on insect damage.

Preliminary observations by the author on field corn in the lower Yakima Valley of Washington in 1947, indicated that corn grown on previously uncropped soil fertilized with 240 pounds of nitrogen per acre was damaged less severely and had a lower infestation of corn earworms, *Heliothis armigera* (Hbn.), than corn grown without nitrogen fertilizer. The infestation decreased from 100 per cent on the unfertilized plots to 86 per cent on the fertilized plots, and the mean number of injured kernels in a sample of 500 was reduced from 108 to 20.

METHODS.—Observations on the effects of soil fertility on corn earworm damage were continued in 1948 at the Irrigation Experiment Station, Prosser, Washington, in connection with a study made of Golden Cross Bantam sweet corn yields and quality on newly irrigated land as affected by winter cover crops, manure, nitrogen supply, and plant spacings. Details of the experimental plan and horticultural aspects of the study are given by Clore & Viets (1949). The 32 combinations of treatments were arranged in a split-plot factorial design of four replications.

Corn earworm damage was assessed by grading each usable ear of corn according to the extent of worm feeding as follows: Grade 1, no damage; Grade 2, tip damage; Grade 3, feeding injury extending more than an inch below the tip. Earworm damage also was determined as the weight lost in trimming damaged portions from 25 randomly selected ears in each plot. In addition, the number of infested ears was recorded.

Growth rates of earworms were determined by rearing larvae in the laboratory on corn ears taken from each nitrogen level in the vetch pretreatment. Four larvae were used in each treatment. Measurements were made of the increase in size and weight of the worms from the second instar to the pupal stage. Respiration rates of the same worms were determined by measuring oxygen consumption in a differential manometer.

RESULTS.—Significant differences between treatments were apparent in the percentage of infestation, the damage grade, and the percentage of trim (Table 1). No significant differences in respiration or rate of growth of the worms were found.

Analysis of the data showed highly significant differences in insect injury between plots receiving various amounts of nitrogen and significant differences between the winter pretreatments. Worm damage at a 6-inch plant spacing within the row was not significantly different from that at 9-inch spacing. The differences in infestation as a result of the treatments are shown graphically in figure 1. Least damage occurred on plots receiving the 160-pound nitrogen-vetch treatment. These plots had 81 per cent infested ears and a grade of 2.32, compared with 100 per cent and a grade of 2.97 on the check.

Corn on the various plots did not silk at the same time. Differences in infestation as affected by silking date are given in table 2.[2]

DISCUSSION.—The increase in nitrogen application to the soil had the following effects on the sweet corn in this experiment:

1. Induced earlier silking and consequent early maturity.
2. Increased the number and size of ears and decreased the number of barren stalks.
3. Increased the length of husk extension and the tightness of husks.

All these factors could affect the worm infestation and the amount of damage.

[1] Published as Scientific Paper No. 914, Washington Agricultural Experiment Stations, Institute of Agricultural Sciences, The State College of Washington, Pullman.

[2] Data on silking dates were taken by Clore and Viets (1949) but were not published.

The increase in infestation as the silking date was delayed, even on plots of comparable fertility, indicates that a difference in moth population existed at the different silking dates, resulting in differences in worm infestation. However, as shown in table 3, on plots of different fertility levels which silked at the same time, corn receiving high fertility treatments had a lower infestation than corn grown on soils of low fertility. This indicates that factors other than differences in moth population affected the results.

Because more ears were available for oviposition on the high fertility treatments, the chance of an ear being attacked would be reduced, assuming a uniform moth population. Such an effect of yield on insect infestation has been noted in the case of codling moths on apples (Hansberry & Richardson 1935).

A long, tight husk usually is associated with freedom from earworm attack (Douglas 1947). In the low fertility plots in this experiment, the husks scarcely covered the tips of the ears, making them more susceptible to attack. Under high fertility conditions, the long, tight husks in many cases caused feeding to be confined to the silk channel and the tip of the ear.

Since the kernels on the low fertility treatments were small and slow to mature, an earworm would need to eat a larger portion of a smaller ear to obtain sufficient nutrient for full development than in the case of the larger, early maturing ears from high fertility treatments.

The limited tests showed no apparent differences in growth rate or metabolism of worms from different treatments such as could be expected if the corn differed in feeding value. Thus, it is probable that the differences in physical characters of the plants produced under different fer-

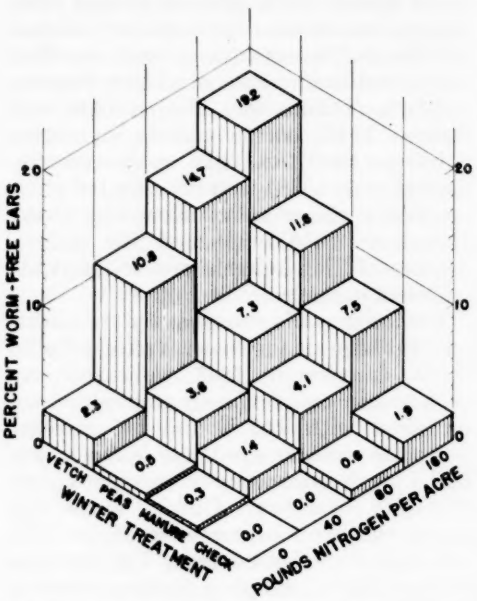

FIG. 1.—Effect of winter pretreatment and nitrogen fertilizer on the infestation by corn earworms in sweet corn.

Table 1.—Effect of soil fertility on corn earworm infestation and damage.

Treatment	Infested Ears		Amount of Trim		Average Grade of Damage
	Per Cent	Equivalent Angles	Per Cent	Equivalent Angles	
Nitrogen per Acre					
0 lbs.	99.5	86.11	—	—	2.75
40 lbs.	98.0	80.75	8.2	16.65	2.63
80 lbs.	94.6	76.60	6.7	14.99	2.51
160 lbs.	91.0	72.59	5.3	13.30	2.32
Least Significant Difference					
1% level		5.09		1.46	0.16
5% level		3.80		1.08	0.12
Winter Pretreatment					
Check	99.7	86.98	8.9	17.31	2.82
Manure	97.4	80.65	6.8	15.11	2.60
Austrian Winter Peas	95.2	77.39	6.1	14.33	2.47
Hairy Vetch	89.4	71.00	5.2	13.17	2.31
Least Significant Difference					
1% level		10.61		2.08	0.24
5% level		15.24		3.00	0.34

Table 2.—Effect of date of 50 per cent silking on earworm infestation.

SILKING DATE	NO. OF PLOTS	TOTAL EARS	PER CENT INFESTED
August 4	3	312	37.6
August 5	2	153	68.5
August 10	44	3,463	84.4
August 12	15	734	86.4
August 17	62	3,595	95.1

Table 3.—Infestation of earworms in plots of different fertility treatments which had reached at least 50 per cent silking on August 10, 1948.

TREATMENT	NO. OF EARS		PER CENT INFESTED
	Usable	Total	
Check			
0 lbs. N.	5	14	100.0
40 lbs. N.	10	28	100.0
80 lbs. N.	22	40	100.0
160 lbs. N.	49	78	100.0
Manure			
0 lbs. N.	5	21	100.0
40 lbs. N.	34	42	100.0
80 lbs. N.	69	82	95.6
160 lbs. N.	83	114	85.5
Austrian Winter Peas			
0 lbs. N.	23	41	100.0
40 lbs. N.	26	36	96.2
80 lbs. N.	69	73	91.3
160 lbs. N.	57	83	82.5
Hairy Vetch			
0 lbs. N.	28	36	89.3
40 lbs. N.	72	98	87.5
80 lbs. N.	75	86	85.3
160 lbs. N.	75	104	76.0

tility treatments are most likely responsible for the observed differences in infestation and damage. Any differences in the nutritive quality alone would be of secondary importance.

Further studies to ascertain the reasons for these differences were prevented by an absence of corn earworms in 1949, apparently due to a high winter mortality. At fertility rates high enough to produce good yields of corn, differences in damage and infestation, though statistically significant, were insufficient to hold promise for nitrogen fertilizer alone as a control for corn earworms. However, the results favor the maintenance of a high level of soil fertility. Also these differences indicate that differential insect attacks should be considered in determining yields and quality in experiments on soil fertility.

SUMMARY AND CONCLUSIONS.—Differences were found in corn earworm infestation and damage to field corn and sweet corn grown with increasing rates of nitrogen fertilizer. An increase in nitrogen resulted in less earworm damage.

The differences were attributed to possible lower moth populations at the earlier dates of silking on the high fertility plots; to the greater number of ears on high fertility plots; to the increased length and tightness of husks on the high fertility corn; and to the larger size of the ears on the high fertility corn which would result in less kernel consumption to fill the food requirements of the worms. Differences in actual nutritive value of the corn for the earworm, if any, are of secondary importance. Although reduction in infestation and damage was not sufficient to indicate that increase of soil fertility would serve as a practical control for earworms, the degree of control serves as an additional inducement for the farmer to maintain high soil fertility.

LITERATURE CITED

Clore, W. J., and F. Viets, Jr. 1949. Sweet corn fertility studies on newly irrigated land in the Yakima Valley. Proc. Amer. Soc. Hort. Sci. **54:** 378–84.

Dahms, R. G. 1947. Oviposition and longevity of chinch bugs on seedlings growing in nutrient solutions. JOUR. ECON. ENT. **40**(6): 841–5.

Dahms, R. G., and F. A. Fenton. 1940. The effect of fertilizers on chinch bug resistance in sorghums. JOUR. ECON. ENT. **33**(4): 688–92.

Douglas, W. A. 1947. The effect of husk extension and tightness on earworm damage to corn. JOUR. ECON. ENT. **40**(5): 661–4.

Evans, A. C. 1938. The effect of the chemical composition of the plant on reproduction and production of winged forms in *Brevicoryne brassicae* L. (Aphidae). Ann. Appl. Biol. **25:** 558–72.

Garman, P., and B. H. Kennedy. 1949. Effect of soil fertilization on the rate of reproduction of the two-spotted mite. JOUR. ECON. ENT. **42**(1): 157–8.

Hansberry, T. H., and C. H. Richardson. 1935. A design for testing technique in codling moth spray experiments. Iowa State Col. Jour. Sci. **10**(1): 27–35.

Haseman, L. 1946. Influence of soil minerals on insects. JOUR. ECON. ENT. **39**(1): 8–11.

McGarr, R. L. 1943. Relation of fertilizers to the development of the cotton aphid in 1941 and 1942. JOUR. ECON. ENT. **36**(4): 640.

Wittwer, S. H., and L. Haseman. 1946. Soil nitrogen and thrips injury on spinach. JOUR. ECON. ENT. **38**(5): 615.

Further Tests for Earworm Control in Sweet Corn

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Keeping earworms, *Heliothis armigera* (Hbn.), out of sweet corn is one of the most important problems in producing marketable ears in North Carolina. Earworm infestations are usually widespread and occur early. Early sweet corn as well as late-grown corn is subject to severe attack. Heretofore, control work has been done with mineral oil, organic insecticides as sprays or dusts, as well as by different methods of application. Previous research work has been described in an earlier paper (Kulash 1948).

This paper is a report on the materials and methods used for control of earworms in sweet corn in tests conducted during the early part of 1949.

PURPOSE OF THE 1949 TESTS.—The chief purposes of the 1949 earworm tests were: (1) to continue tests with some of the materials that had proved most promising in previous control tests; (2) to test some new insecticides; and (3) to compare the efficiency of spray and dust formulations of the same toxicant in controlling earworms.

MATERIALS USED.—Five different toxicants were used in spray and dust formulations. The sprays and dusts were so formulated that, applied at the usual rates per acre, the same amount of toxicant per acre was used with either type of formulation. Approximately one or two pounds of toxicant were applied per acre with either type of formulation. Check treatments were neither dusted nor sprayed. For a listing of the dusts and sprays used, see table 1.

In order to check on possible increased efficiency of the performance of the various liquid toxicants, one row of each plot was treated with toxicant which had sticker added to it at the rate of 1.5 pounds of a sticker per 100 gallons of finished spray. The sticker was a commercial brand[1] prepared from natural animal proteins. A comparison of rows treated with insecticide-sticker versus rows treated with insecticide alone is presented in table 3.

PROCEDURE.—Oiling has been considered an effective control method but this season's treatments were confined to spray and dust applications rather than oil applications of oil by itself or in combination with an organic insecticide. Dust and spray treatments are easier to apply and do not interfere with the pollination of corn. Hence, they are considered to be more practical and because of this, only spray and dust formulations were used in 1949.

Sprays and dusts were applied directly to the silk channel of the ear. The sprays were applied as a solid stream usually for a period of 2 or 3 seconds per ear—or enough to wet the silk thoroughly. Dusts were applied with a plunger type hand duster at an estimated 20 pounds per acre. In most instances, finished dust formulations were prepared from concentrates supplied by the manufacturer. In all

Table 1.—Insecticide formulations for corn earworm control. Raleigh, N. C.—1949.

MATERIALS	PERCENTAGE OF CLEAN EARS	
	First Planting[2]	Second Planting[2]
Sprays: (per cent emulsion concentrate)[1]		
25% dichlorodiphenyl dichloroethane[3]	87.7	82.0
25% 2-nitro-1, 1-bis (p-chlorophenyl) propane[4]	82.0	85.7
25% 2-nitro-1, 1-bis (p-chlorophenyl) butane[4]	78.3	75.9
25% DDT[5]	74.8	83.3
42% Toxaphene[5]	67.6	70.8
Untreated Check	52.1	56.9
Dusts:		
10% Toxaphene	93.6	69.8
5% dichlorodiphenyl dichloroethane[3]	91.2	74.3
5% DDT	89.4	87.7
5% 2-nitro-1, 1-bis (p-chlorophenyl) propane[4]	76.0	65.9
5% 2-nitro-1, 1-bis (p-chlorophenyl) butane[4]	65.2	79.4

[1] Finished sprays formulated by addition of 1 ml. of concentrate to 100 ml. water except as follows: 1 ml. of 42% toxaphene added to 168 ml. water.
[2] Average of two replicates in each of two plantings.
[3] Supplied by Rohm and Haas, Philadelphia, Pennsylvania.
[4] Supplied by Commercial Solvents Corporation, New York.
[5] Supplied by Acme White Lead and Color Works, Detroit, Michigan.

[1] Armour Sticker, supplied by Armour and Company, Chicago, Illinois.

Table 2.—Percentage of clean ears in spray and dust treatments of 2 plantings of sweet corn.[1]

MATERIAL	PER CENT CLEAN EARS
DDT	83.8
Dichlorodiphenyl dichloroethane	83.8
2-nitro-1, 1-bis (p-chlorophenyl) propane	77.4
Toxaphene	75.5
2-nitro-1, 1-bis (p-chlorophenyl) butane	74.9
Untreated check	52.9
	L.S.D. 1% level, 15.7

[1] Total of—
Two replicates for each toxicant used in
Two formulations in
Two plantings.

such cases, attapulgite (Fuller's earth) was used as the diluent.

Sprays were prepared from emulsion concentrates of varying concentration and diluted with water at the rate indicated in footnote 1 of table 1.

PLOT ARRANGEMENT.—Sprays and dusts were applied to plots consisting of two rows each 50 feet long. Each plot consisted of two replicates. All spray treatments were randomized in one section of the test area. Dust treatments were randomized in an adjacent section of the field. Insecticidal treatments were applied to two separate plantings of Golden Cross Bantam corn. The first planting was seeded on April 15 and ear treatments were begun on June 20. Five spray and dust applications were made at 3-day intervals, the last application being made on July 2. Picking of corn from the first planting was begun on July 3 and completed on July 9.

The second planting was seeded on May 7 and treatments of ears were begun on June 30. This planting had five applications at 3-day intervals. The last application was made on July 12. First ears from the second planting were picked on July 14 and picking was completed on July 21.

Table 3.—Per cent of ears with worms in corn treated with insecticide without sticker vs. corn treated with insecticide with sticker.

INSECTICIDE	FIRST PLANTING		SECOND PLANTING	
	With Sticker	No Sticker	With Sticker	No Sticker
Toxaphene	56.0	79.2	75.0	66.7
DDT	64.3	85.2	82.8	83.7
Dichlorodiphenyl dichloroethane	78.9	96.3	88.9	75.0
2-nitro-1, 1-bis (p-chlorophenyl) propane)	84.6	79.4	83.3	88.0
2-nitro-1, 1-bis (p-chlorophenyl) butane	77.3	79.2	72.1	79.6

Counts were made of the number of clean and wormy ears as the ears became mature and of a size that would ordinarily be picked. Each ear was examined by stripping the husk half-way down the ear. A clean ear was scored as such when there was no evidence of an earworm or of earworm damage. A wormy ear was scored wormy even though the worm had not yet caused any appreciable damage. It will be noted that this procedure of scoring differs from that reported by Greenwood & Hofmaster (1949) who scored corn as marketable or non-marketable depending on the condition of worm damage in the ear and not on the presence of worms therein.

In addition to the infestation records, an attempt was made to check on the quality of treated corn. This was done by having corn that had undergone the same treatment tested for taste and off-flavor by two different groups of tasters. The taste testers were members of the college staff who had not been previously warned of the fact that the corn had been treated for control of earworms.

RESULTS OF INSECTICIDAL TREATMENT.—A statistical analysis of the results obtained with spray and dust formulations indicated that there was no significant difference between the two methods of application of toxicants. This was true in both the first and the second plantings.

The performance of the various toxicants exhibited a considerable amount of variation. There was no correlation between the performance of a toxicant in the first planting as compared with its performance in the second planting. Amongst the spray treatments in the first planting, the greatest percentage of clean ears was scored in the dichlorodiphenyl dichloroethane treatment; with the 2-nitro-1, 1-bis (p-chlorophenyl) propane treatment second; and the 2-nitro-1, 1-bis (p-chlorophenyl) butane treatment third. Amongst the dust treatments in the same planting, the greatest percentage of worm-free ears was produced first in the 10-per cent toxaphene treatment, followed by 5-per cent dichlorodiphenyl dichloroethane and 5 per cent DDT. All of these treatments were significantly better than the untreated checks.

In the second planting, the following

treatments had the best performance amongst the sprays: 2-nitro-1, 1-bis (p-chlorophenyl) propane, first; DDT, second; and dichlorodiphenyl dichloroethane, third. All of these were significantly better than the untreated check.

The best dust treatments of the second planting were as follows: 5 per cent DDT, first; 5 per cent 2-nitro-1, 1-bis (p-chlorophenyl) butane, second; and 5 per cent dichlorodiphenyl dichloroethane, third.

A comparison of the rows treated with spray containing sticker and rows sprayed with materials containing no sticker shows that the rows treated with materials containing sticker were generally more heavily infested than the no-sticker row (Table 3). In the first plantings, four out of five treatments with sticker had more wormy ears than the same treatments without sticker; in the second planting, three treatments out of five using sticker had more worms. This difference in number of worms in treatments with sticker versus treatments without sticker was not statistically significant.

Reports on taste tests by the various groups of tasters indicated no off-flavor that could be ascribed to any of the insecticidal treatments. It is highly probable that in cases where the silks have not been destroyed or eaten by earworms, it would be difficult for a spray or dust to get on the kernels. In the case of ears with damaged silks, sprays or dusts may be deposited on the kernels at the tip end of the ear. During the past 4 years, our observations on spraying and dusting the ears indicate that no objectionable insecticidal odor is left on the kernels.

A statistical analysis of the performance of the dust and spray treatments in the two separate plantings showed that there was no significant difference amongst the results obtained in the two plantings either due to type of formulation or time of planting. The spray and dust treatments of both plantings were grouped together and analyzed on the basis of toxicant alone. This analysis shows the following rank based on percentage of clean ears: first, DDT, tied with dichlorodiphenyl dichloroethane; second, 2-nitro-1, 1-bis (p-chlorophenyl) propane; third, toxaphene; fourth, 2-nitro-1, 1-bis (p-chlorophenyl) butane; and, fifth, untreated check. All materials were significantly better than the untreated check (see table 2).

SUMMARY.—The results of tests for the control of earworms attacking Golden Cross Bantam sweet corn are presented. Ten spray and dust formulations were used, representing five different toxicants. Two separate plantings of sweet corn were treated a total of five times. Treatments were made at 3-day intervals.

There was no correlation in the performance of the different materials between the two separate plantings. There was no significant difference between the 2 methods (spray and dust) of treatment. All materials were significantly better than the untreated check and ranked as follows:

MATERIAL	PER CENT CLEAN EARS
DDT	83.8
Dichlorodiphenyl dichloroethane	83.8
2-nitro-1, 1-bis (p-chlorophenyl) propane	77.4
Toxaphene	75.5
2-nitro-1, 1-bis (p-chlorophenyl) butane	74.9
Untreated check	52.9

Corn from any treatment did not have an objectionable odor or taste.

LITERATURE CITED

Greenwood, D. E., and R. N. Hofmaster. 1949. Corn earworm control studies in Virginia. JOUR. ECON. ENT. **42**(4): 675–7.

Kulash, W. M. 1948. New insecticides for corn earworm control. JOUR. ECON ENT. **41**(3): 387–9.

Small Scale Field Evaluation of Insecticides for Corn Borer Control[1]

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Laboratory tests have been designed to determine rapidly if chemicals are toxic to the European corn borer, *Pyrausta nubilalis* (Questel *et al.* 1941). Moderate to large-scale field tests which may involve large acreages have also been carried out by numerous workers. In an effort to bridge these two extremes yet maintain considerable experimental control over influencing factors we have devised a single plant, small plot technique and used it during the past growing season.

By this technique it is possible to be assured of an infestation and to use uniform infestations, thus avoiding much of the variation which ordinarily occurs in the field. The small plot technique provides certain features not present in laboratory tests. Corn borer larvae are permitted to exist on growing plants under field conditions and to contact the treated plant as they would under normal conditions of plant growth. It is possible to evaluate a great many different chemicals, different formulations and different combinations of timing of borer infestation and application of the insecticide. It would also be possible to evaluate the efficiency of different chemicals, formulations and timings for various levels of infestation. Advantages over large acreage tests include the ability to make a large number of tests in a relatively small area and with considerably less labor and time involved. The flexibility of field plot design and arrangement is also much greater with this method than with the usual field tests. Certain designs can thus be used which eliminate undesirable variables.

As with any technique limitations occur. These limitations will be pointed out later in the discussion. But even the main limitations which have been observed are apparently amenable to correction. In spite of some limitations the advantages of the technique over laboratory tests and field tests relying on variable natural infestations are considerable.

Procedure.—The single plant, small plot technique employs the placement of a known and uniform number of laboratory produced egg masses on the corn plant. The egg masses can be placed on the plants at any of the stages of development of the plant at which infestation may occur normally. In our preliminary tests with the technique we have placed the egg masses on the plants during the whorl stage at which infestation by first brood borers normally occurs, and also later during the formation of the ear at which stage infestation by second brood borers normally takes place.

Hand infestation of plants in the whorl stage was developed by Patch & Peirce (1933) for studying resistance of corn to first brood borers. We have adapted the technique to the needs of studies of insecticides and insecticidal protection. Further information on the procedures for producing egg masses and their use in corn borer research is given elsewhere (Holdaway).

The timing of the application of an insecticide in relation to infestation is a critical relationship in evaluating the efficiency of a material. Two different types of study have been made. The first involved the application of three egg masses about to hatch ("black-head" stage) to each plant during the late whorl stage with application of insecticides two days later. The second type of study, more important from the standpoint of residual qualities of an insecticide, involved application of the insecticides one day before the first egg masses were placed on the treated plants. Egg masses were placed near the ear tip on three successive days following application of the sprays.

In our experiments randomization was made with three replications in each of two varieties of sweet corn. Treatments were made only on alternate rows using every other plant, thus providing an untreated buffer plant on all four sides of the sprayed plant. Applications were made with compressed air hand sprayers operating at 40 pounds pressure for a

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period of 3 seconds in the area of each plant selected for treatment. The rate of application was about 90 gallons per acre. A metal shield held behind the plant being treated prevented drift of the spray material to other plants.

MATERIALS.—Insecticides used in this study included a 47 per cent emulsion of aldrin, a 25 per cent emulsion and a 15 per cent wettable powder concentrate of dieldrin, a 25 per cent emulsion of DDT, and 50, 75 and 90 per cent wettable powders of DDT, a 25 per cent emulsion of dichlorodiphenyl dichloroethane and 2,2-bis-(p-fluorophenyl)1,1,1-trichloroethane,[1] a 25 per cent wettable powder of the latter, a 50 per cent wettable powder of the tolyl analogue of DDT (2,2-bis-(p-tolylphenyl)1,1,1-trichloroethane,[2] 25 per cent emulsion of two nitroparaffins, 2-nitro-1,1-bis(p-chlorophenyl)propane,[3] and 2-nitro-1,1-bis(p-chlorophenyl) butane,[3] a 31.5 per cent wettable powder of ethyl p-nitrophenyl thiophosphonate,[4] a 25 per cent wettable powder of heptachlor, a 25 per cent emulsion of methoxychlor, a 16 per cent parathion emulsion and a mixed emulsion concentrate consisting of 12.7 per cent DDT and 3.9 per cent parathion, a 25 per cent wettable powder of parathion, a 4 per cent rotenone powder and a sample of dihydrorotenone[5] (m.p. 216° C.) prepared for use as a suspension, ground ryania, and a 40 per cent solution of tetraethyl pyrophosphate, referred to as TEPP.

RESULTS.—The results obtained must be regarded as preliminary. They are given here, however, primarily to illustrate the possibilities of the experimental technique. Tables 1 and 2 contain the results of tests emphasizing the immediate toxicity of the insecticides, *i.e.* when the application of the insecticides was made after the plants had been infested and just after hatching of the eggs. Tables 3 and 4 emphasize residual toxicity since the insecticide was applied prior to placement of the egg masses. Table 2 presents results of immediate toxicity and table 4 residual toxicity of wettable powder and emulsion formulations of each insecticide where the insecticide was used at a uniform concentration and rate of application and the comparison could logically be made.

Materials with a high immediate toxicity at the concentrations tested have been found to be a wettable pwoder of heptachlor, emulsions of dieldrin, a parathion-DDT mixture, parathion and aldrin, a DFDT wettable powder, a TEPP water solution, and a wettable powder of EPN.[4] The DDT wettable powders of 75 and 90 per cent concentration were nearly as effective (Table 1). Ryania is not included in this comparison because it was inadvertently prepared at too low a concentration.

[1] Referred to as DFDT.
[2] Geigy Co., Inc.
[3] Commercial Solvents Corp. (CS-645A and CS-674A).
[4] E. I. DuPont Co.—EPN.
[5] Div. Insecticide Inv., Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

Table 1.—First study emphasizing immediate toxicity. Comparison of the most efficient insecticides applied as sprays to two varieties of sweet corn. Three egg masses near hatching were placed centrally in the whorl of each plant and spray applications were made about 48 hours later.

INSECTICIDE	FORMULATION	RATE, LBS. PER 100 GAL.	ANTHERS INJURED PER PLANT		PER CENT REDUCTION (BOTH VARIETIES)
			Golden Cross	Minn. Valley Hybrid	
Heptachlor	Wettable	1.0	17	20	79
Dieldrin	Emulsion	0.5	12	26	78
Parathion-DDT mixed	Emulsion	0.15 0.5	29	11	77
Parathion	Emulsion	0.5	29	13	76
Aldrin	Emulsion	0.75	30	23	70
DFDT	Wettable	1.25	32	23	68
TEPP	Solution	0.4	35	21	68
Parathion	Emulsion	0.3	41	20	65
DFDT	Emulsion	1.0	37	27	64
EPN	Wettable	0.75	57	17	57
DDT	Wettable (90%)	1.0	40	40	54
Untreated	—	—	124	50	—
Significant difference at 5% level			54	28	

Table 2.—First study emphasizing immediate toxicity. Comparison of the efficiency of sprays of emulsions and wettable powders of various insecticides. Three egg masses near hatching were placed centrally in the whorl of each plant and spray applications were made about 48 hours later.

Insecticide	Formulation	Rate, Lbs. per 100 Gal.	Golden Cross		Minn. Valley Hybrid		Both Varieties, Per Cent Reduction
			Number Anthers Injured	Per Cent Reduction	Number Anthers Injured	Per Cent Reduction	
Parathion	Emulsion	0.5	29	77	13	75	76
Parathion	25% Wettable	0.5	75	39	5	93	54
Dieldrin	Emulsion	0.5	12	90	26	49	78
Dieldrin	15% Wettable	0.5	75	40	30	40	40
DFDT	Emulsion	1.0	37	70	27	47	68
DFDT	25% Wettable	1.0	136	0	32	37	5
TDE	Emulsion	1.25	73	41	26	48	43
TDE	50% Wettable	1.25	72	42	67	0	20
DDT	Emulsion	1.0	68	45	31	38	43
DDT	50% Wettable	1.0	77	38	48	5	29
DDT	75% Wettable	1.0	55	55	25	50	54
DDT	90% Wettable	1.0	40	68	40	20	54
Untreated	—	—	124		50		
Significant difference at 5% level=			28		No significant difference between treatments		

Comparisons of formulations revealed that emulsions of compound dieldrin and DFDT were significantly more effective in immediate kill than were wettable powder sprays. There is a definite trend in the same direction with parathion and TDE. With DDT, however, wettable powders of three concentrations were compared with the emulsion, but the emulsion was not superior to the wettable powders (Table 2). When the immediate toxicity of an insecticide is an important factor an insecticide which deteriorates rapidly, such as tetraethyl pyrophosphate, may still be quite efficient (Table 1). However, from the standpoint of residual effectiveness, TEPP was the poorest material tested (Table 3).

Residual effectiveness as shown in the second study when egg masses were not placed on the plants until some days after the sprays had been applied was found to be high in the following materials in the order given: wettable powders of EPN and heptachlor, aldrin emulsion, DFDT wettable, *CS-645A* emulsion, dieldrin wettable, parathion-DDT emulsion, DDT 90 per cent wettable, *CS-674A* emulsion, rotenone suspension, parathion emulsion, DDT 75 per cent wettable, dihydrorotenone and Ryania suspensions. Dieldrin and TDE emulsions were less effective. The tolyl analogue of DDT and methoxychlor were still less effective while tetraethyl pyrophosphate apparently showed no residual action. The nitroparaffin, *CS-645A* compared quite favorably considering the concentration used (Table 3). In interpreting these results it should be realized that these comparisons are with a comparatively short time for the residual effect to operate. The relative efficiency of the insecticides might be changed in a study involving a longer period of time.

Differences in efficiency due to formulation, which were apparent in the first study in which immediate toxicity was important, were not as apparent in the second study in which residual action was important (Table 4). There was, however, a trend in the opposite direction, *i.e.* greater efficiency of the wettable powder sprays with all the insecticides studied except parathion (Table 4). The greater efficiency of the wettable powder over the emulsion was statistically significant with DFDT.

No rainfall was recorded during the study involving residual effectiveness.

Some of the materials found highly effective either as regards immediate kill or residual action were used at concentrations slightly higher than might be con-

sidered economically practical at the present time. Further studies with somewhat lower concentrations should reveal those materials which exhibit high efficiency together with economy.

In studying the tables one can see that the variety Golden Cross Bantam[1] sustained much more injury (also evident in numbers of live borers) than did the other variety. Also the effectiveness of certain insecticides or certain formulations was not always similar with both varieties. The varieties were planted on the same date and in the same plot, but the Golden Cross Bantam variety was three or four days longer in maturing. This difference in the time of maturity does not explain the differences in the number of borers at the end of the study. The difference in levels of the number of borers on the varieties suggests a difference in susceptibility. Whatever the explanation may be the results indicate that the technique would permit a comparison of the efficiency of an insecticide, formulation or method of application on different varieties grown and studied under the same conditions. Such an approach of study deserves further consideration in experimentation.

The results obtained, which suggest that the protective action of a given insecticide or formulation may be different on different varieties, has led to a reduction of the numbers of replications that could be used in the analysis of the results for each insecticide or formulation. This leads also to a reduced level of statistical significance of such data as have been secured so far. Thus, in future studies, there will be a need for more replications on each variety since one cannot assume that a comparison of treatments on one variety will be similar on another.

One factor which initially had seemed to be a disturbing element in the studies was the presence of predators (principally Chrysopidae). The larvae of these insects were especially common during the second study (mid-July). Their presence makes proper evaluation of the results more difficult because of their destruction of

[1] Acknowledgement for supplying seed of the two sweet corn varieties is due to Minnesota Valley Canning Co., Le Sueur Minnesota.

Table 3.—Second study comparing insecticides when residual action of the spray was important. Egg masses were placed on the tip of the developing ear one, two and three days following application of the sprays.

Insecticide	Formulation	Rate, Lbs. per 100 Gal.	Total Ear Injuries[1] Sweet Corn Varieties		Both Varieties Per Cent Reduction	
			Golden Cross	Minn. Valley Hybrid	Over Untreated	Over TEPP
EPN	Wettable	0.75	2.7	2.3	79	85
Heptachlor	Wettable	1.0	5.3	0.0	77	85
Aldrin	Emulsion	0.75	2.7	3.3	74	83
DFDT	Wettable	1.0	6.0	0.3	73	82
CS-645A	Emulsion	0.5	8.7	1.3	56	70
Dieldrin	Wettable	0.5	7.7	4.3	49	65
Parathion-DDT mixed	Emulsion	0.15 0.5	9.7	3.7	43	61
DDT	90% Wettable	1.0	10.7	3.3	40	59
CS-674A	Emulsion	0.5	10.7	3.7	39	58
Rotenone	Wettable	0.25	12.3	2.3	20	57
Parathion	Emulsion	0.5	14.0	1.0	18	56
Parathion	Wettable	0.5	13.0	2.0	18	56
DDT	75% Wettable	1.0	11.0	4.3	16	55
Dihydrorotenone	Wettable	0.25	9.5	6.3	14	54
Ryania	Wettable	6.0	10.0	6.7	9	52
Dieldrin	Emulsion	0.5	13.7	4.3	2	48
TDE	Wettable	1.25	11.0	7.0	2	48
Untreated			10.3	8.0		48
Tolyl analogue of DDT	Wettable	1.25	14.0	8.0	0	36
Methoxychlor	Emulsion	3.0	18.7	8.3	0	21
TEPP	Solution	0.4	23.7	10.7	0	—
Significant difference at 5% level			12.3	6.1		

[1] See Table 4 for explanation of injuries.

Table 4.—**Second study comparing the efficiency of emulsions and wettable powders when the residual was important. Artificial infestations were used and the spray applications preceded egg placement on the forming ear. Egg masses were placed on the 1st, 2nd, and 3rd days following spraying, using one egg mass each day.**

Insecticide	Formulation	Rate	Golden Cross		Minn. Valley Hybrid		Both Varieties Per Cent Reduction
		Lbs. per 100 Gal.	Total Ear Injury Sites[1]	Per Cent Reduction of Injury[2]	Total Ear Injury Sites[1]	Per Cent Reduction of Injury[2]	
DFDT	25% Wettable	1.0	6.0	75	0.3	97	82
DFDT	Emulsion	1.0	13.3	44	7.3	31	39
Dieldrin	15% Wettable	0.5	7.7	68	4.3	59	65
Dieldrin	Emulsion	0.5	13.7	42	4.3	59	48
DDT	50% Wettable	1.0	8.7	63	12.3	0	31
DDT	75% Wettable	1.0	11.0	54	4.3	59	55
DDT	90% Wettable	1.0	10.7	55	3.3	69	59
DDT	Emulsion	1.0	17.7	25	5.3	50	33
TDE	50% Wettable	1.25	11.0	54	7.0	34	48
TDE	Emulsion	1.25	16.3	31	5.0	53	38
Parathion	25% Wettable	0.5	13.0	45	2.0	81	56
Parathion	Emulsion	0.5	14.0	41	1.0	91	56
Untreated	—	—	10.3	57	8.0	25	47
TEPP	Solution	0.4	23.7	—	10.7	—	—

No significant differences between formulations, except DFDT when both varieties are considered.
[1] Injury includes outer and inner husk holes, silks cut, ear penetration and number of kernels injured.
[2] Reduction based upon tetraethyl pyrophosphate as a control.

young corn borer larvae and eggs. To a large extent this accounts for the low population in the untreated plants. Presumably many of the predators are killed by many insecticides but differential susceptibility may have influenced the results somewhat.

One possible approach towards minimizing the effect of a predator or parasite on the borer population under study appears to be to use a rapidly deteriorating insecticide of high initial toxicity. Such an insecticide could also be used to reduce or nearly eliminate any natural insect infestations which are susceptible to the insecticide. Tetraethyl pyrophosphate appears quite suitable for obtaining such a desired result. Its comparatively high initial toxicity to corn borer larvae is shown in table 1. An effect on predators can be shown indirectly by the study on residual action where the plants treated with TEPP contained more surviving borers and consequently sustained more injury than the untreated plants. The hydrolysis and concomitant decrease in toxicity of TEPP has already been demonstrated (Harris 1947). Since a predator problem was present in the residual study reported in tables 3 and 4 we feel justified in using tetraethyl pyrophosphate as a unique and valuable control in reporting the results obtained. Furthermore, we feel that the use of this insecticide as a tool for minimizing or eliminating the effects of naturally occurring competitive or destructive populations may be quite valuable in many different studies.

SUMMARY AND CONCLUSIONS.—A small scale field method of evaluating insecticides for control of the European corn borer has been developed and used in which corn plants were hand infested by near-hatching egg masses. The technique has considerable possibilities in studies of timing of the borer infestation and application of an insecticide. In addition the evaluation of the effectiveness of an insecticide at high and low level populations of insects is possible as well as studies involving predator relationships. Experimental design is also quite flexible with this method. In general, evaluation of borer damage can be made in more detail than in most field experiments.

Studies made during the past growing season included the use of sprays applied in two different tests before and after

placement of egg masses on plants. Results are given of a comparison of the efficiency of wettable powder and emulsion formulations of five insecticides. Comparisons of the toxicity of several other insecticides are included. In general, most of the emulsions showed a greater efficiency than the wettables at the time of initial kill but not in their residual effect. Exceptions were the 75 and 90 per cent wettable powders of DDT which were more effective in both studies. As regards residual action, the wettable powder sprays were, in general, more efficient than were the emulsions under the conditions of no rainfall prevailing during the experiments. The forms of parathion and TDE did not differ appreciably in effectiveness in the residual study.

Results obtained also indicate that a highly toxic material which deteriorates rapidly when sprayed, such as tetraethyl pyrophosphate, may serve as a useful tool in certain types of study. By its use populations of insects undesirable for the study may be reduced or nearly eliminated 24 or 48 hours prior to the introduction of an artificial infestation. Experimental work with the artificially infested plants may then proceed free from the competition or destruction caused by other forms.

LITERATURE CITED

Harris, John S. 1947. Tetraethyl pyrophosphate. Agricultural Chemicals **2**(10): 27–9, 65–6.

Holdaway, F. G. Mass rearing of egg masses for research on European corn borer. Proceedings of the 86th meeting of the Entomological Soc. of Ontario, Winnipeg, Nov. 2–4, 1949. Canad. Ent. (in press).

Patch, L. H., and L. L. Peirce. 1933. Laboratory production of clusters of European corn borer eggs for use in hand infestation of corn. JOUR. ECON. ENT. **26**: 196–204.

Questel, D. D., S. I. Gertler, L. E. Smith and D. L. Vivian. 1941. Laboratory and field tests of toxicity of some organic compounds to the European corn borer. U.S.D.A., Bur. Ent. and Plant Quar. **E-557.**

The Control of Insects of Alfalfa and Red Clover in New York

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During 1948, preliminary investigations of the control of 13 species of insects of red clover and alfalfa using nine different organic insecticides as dusts were initiated in Oswego and Cayuga Counties.

In New York State, the first hay crop is usually harvested toward the end of June or in early July. The new summer growth of the aftermath coincides with the adult emergence of many forage crop insects. The insects at this time which are of major importance in most years on legumes in New York and on which the following experiments were conducted include: the clover seed weevils,[1] *Tychius* spp.; the clover root curculio, *Sitona hispidula;* the sweet clover weevil, *Sitona cylindricollis; Sitona flavescens;* the tarnished plant bug, *Lygus oblineatus;* the potato leafhopper, *Empoasca fabae;* the six-spotted leaf-hopper, *Macrosteles divisus;* the clover head weevil, *Hypera meles;* two important species of spittlebugs, the meadow spittlebug, *Philaenus leucophthalmus;* and the lined spittlebug, *P. lineatus;* many species of grasshoppers but especially the red-legged grasshopper, *Melanoplus femur-rubrum* and the two-striped grasshopper, *M. bivittatus*; and several species of aphids but primarily the pea aphid, *Macrosiphum pisi.* For the purpose of this paper, all the grasshoppers are listed together under the heading of "grasshoppers" and no attempt was made to separate the many local and common species. The several species of important aphids are all grouped together as "aphids".

In 1948 nine different insecticides were used as dusts in four separate field experiments located in two counties in north central New York. All the dusts were simple ribbon mill mixtures diluted with

[1] In the latest official list of common names of insects, *Tychius stephensi* is listed as the clover head weevil. It probably should be called the clover seed weevil since it infests only the ovules. The name clover head weevil could be more appropriately applied to *Hypera meles* which feeds on the entire head and does not have a common name.

pyrophyllite or were proprietary formulations. Two levels of concentration of benzene hexachloride, 3 per cent gamma isomer and 6 per cent gamma isomer as well as 3 and 5 per cent dilutions of TDE were prepared with pyrophyllite. Five per cent regular or ribbon mill mixed dusts of chlordane and DDT were also formulated with pyrophyllite. Proprietary mixtures of 1 per cent parathion and two piperonyl cyclonene dusts coded as T-316 and T-247 which were said to contain 0.5 per cent piperonyl cyclonene, 0.25 per cent rotenone and 0.05 per cent pyrethrins in the former and 0.5 per cent piperonyl cyclonene as well as 0.125 per cent pyrethrins in the latter were also used in the various experiments.

Two different methods of dust application were used: a Bell helicopter and a single outlet, even-feed power duster.[2] The duster was mounted on a half-ton pick-up truck with a 10-foot side delivery boom which was approximately 2 feet from the ground and to the right of the truck. The boom, which was made of aluminum alloy, was tubular in shape and constricted slightly throughout its length towards the distal end. A series of equally spaced graded holes on the underside of the boom insured good distribution of the dust. All ground applications of dust were made at a truck speed of approximately 2 m.p.h. The dust mixtures were weighed on a platform scale before application and the residues remaining in the hopper were weighed after application in order to determine the exact amount of each material applied per acre. With the aid of the even-feed mechanism of the dust hopper, it was possible, in most cases, to control the rate of the materials applied per acre with some degree of exactness. The helicopter applications of dust were made at an air speed of approximately 25 m.p.h. flying about 10 feet from the ground. The dust swaths were 40 feet or less in width and overlapped on each side.

At Dexterville, (Table 1) in Oswego County a single application of six different organic insecticides was made on July 15 to an excellent pure stand of 3-year-old alfalfa. The alfalfa was about 6 to 8 inches high at the time of application. The plots which were 20 by 300 feet in size were replicated three times and randomized within blocks. Insect counts were made from 25 net sweeps in each plot 48 and 72 hours after treatment and at weekly intervals for 2 weeks.

Excellent immediate kills of grasshoppers ranging from 96 to 100 per cent were recorded with the use of chlordane, benzene hexachloride and parathion. There were no significant differences between these three treatments. DDT and dichlorodiphenyl dichloroethane, while showing some promise at the concentrations used, were not as effective for controlling grasshoppers as the three previously mentioned materials. Compound T-247, which was relatively ineffective, gave no residual kill. Although adjacent fields still showed heavy populations of grasshoppers, migration of grasshoppers between the treated plots and the untreated checks in this small field greatly reduced the population of the grasshoppers in the untreated plots by the end of 2 weeks.

Benzene hexachloride, parathion, DDT and TDE all proved effective for the control of the tarnished plant bug. No material however proved to be satisfactory for the entire 2-week period although parathion and benzene hexachloride gave up to 90 per cent control of the tarnished plant bugs for about a week. Habits of the tarnished plant bug may in part be responsible for the lack of kill of this insect after one week. This insect largely infests the terminal growth and flower stalks of the alfalfa plant. With plant growth being rapid near bud stage, a large portion of the bug population would not come in contact with the treated foliage and hence would not become affected.

Good immediate and residual control of aphids was obtained with all the materials tested except Compound T-247. Excellent residual control that persisted for 2 weeks, or until the alfalfa was cut, was obtained with benzene hexachloride, DDT and parathion.

While all the materials tested in this experiment showed some promise for the control of spittlebug adults, benzene hexachloride and parathion gave the best immediate reductions of over 98 per cent of the population in 48 hours. The residual toxicity, however, of all the materials at the end of 2 weeks was poor.

Even though counts of the potato leaf-

[2] Niagara Model AA "Even-feed" alfalfa duster powered by a Model ZZ Briggs and Stratton engine.

Table 1.—Summary of 75 net sweeps showing the control of several species of insects of alfalfa with six different organic insecticides applied with a power duster July 15 at Dexterville, New York.

Treatment	Dust Applied per Acre in Pounds	Grasshoppers	*Lygus oblineatus*	*Philaenus leucophthalmus*	*Philaenus lineatus*	*Macrosteles divisus*	*Empoasca fabae*	*Sitona flavescens*	*S. cylindricollis*	*Hypera meles*	Aphids	*Tychius* spp.	Total
48 Hours After Treatment													
DDT, 5%	75	11	8	5	0	0	0	0	0	0	3	0	27
Chlordane, 5%	80	0	9	7	4	0	0	0	0	0	11	0	31
TDE,[2] 3%	60	5	3	3	2	0	0	0	0	0	8	0	21
Piperonyl cyclonene[1]	60	60	11	10	5	1	2	0	0	0	32	0	123
Parathion, 1%	60	0	6	1	0	0	0	0	0	0	0	0	7
Benzene hexachloride, 6% gamma	50	0	7	0	1	1	0	0	0	0	0	0	9
Check	—	210	24	46	13	1	3	0	1	0	144	1	443
72 Hours After Treatment													
DDT, 5%	75	5	23	3	0	0	0	0	0	0	11	0	42
Chlordane, 5%	80	0	17	5	1	0	2	0	0	0	22	0	47
TDE, 3%	60	10	15	7	1	1	1	0	0	0	14	0	49
Piperonyl cyclonene	60	43	23	8	2	2	2	0	0	0	35	0	115
Parathion, 1%	60	4	7	3	1	0	3	0	0	0	6	0	24
Benzene hexachloride, 6% gamma	50	2	6	3	1	0	0	0	0	0	0	0	12
Check	—	126	15	23	5	0	2	0	0	0	99	0	270
1 Week After Treatment													
DDT, 5%	75	5	20	11	1	0	0	1	0	0	3	0	41
Chlordane, 5%	80	2	30	16	0	2	2	0	0	0	23	0	75
TDE, 3%	60	0	30	17	3	2	2	0	0	0	10	0	64
Piperonyl cyclonene	60	14	25	7	1	0	4	0	0	0	136	0	187
Parathion, 1%	60	1	11	7	0	1	8	0	0	0	10	0	38
Benzene hexachloride, 6% gamma	50	1	17	11	5	0	0	0	0	0	3	0	37
Check	—	18	118	16	11	5	8	0	0	0	117	2	295
2 Weeks After Treatment													
DDT, 5%	75	8	45	11	1	0	3	0	0	0	4	0	72
Chlordane, 5%	80	3	57	7	5	1	6	0	0	0	55	0	134
TDE, 3%	60	10	70	12	2	1	5	0	0	0	21	0	21
Piperonyl cyclonene	60	13	55	8	3	0	4	0	0	0	114	0	197
Parathion, 1%	60	5	62	21	3	4	6	0	0	0	9	0	110
Benzene hexachloride, 6% gamma	50	5	72	15	2	0	3	1	0	0	0	0	98
Check	—	15	67	22	4	5	2	0	0	0	121	0	236

[1] *T-247.*
[2] Dichlorodiphenyl dichloroethane.

hopper, six-spotted leafhopper, sweet clover weevil, clover head weevil, clover seed weevil, and *Sitona flavescens* were made in all the insect collections and are recorded in the tables, these insects did not occur in large enough numbers to warrant any conclusions as to the effectiveness of any of the insecticides for their control.

On July 15, a single application of benzene hexachloride, chlordane, TDE and parathion dusts was made to a good pure stand of first crop year medium red clover at Fulton in Oswego County. The clover at this time was 4 to 6 inches tall. The plots, which were 20 by 260 feet in size, were replicated three times and randomized within blocks. Insect counts were made of net sweepings at 48 and 72 hours after application of the dusts and weekly thereafter for 3 weeks. Twenty-five sweeps were taken in random areas in each plot (Table 2). All plots were treated with the power duster.

While there were no significant numbers of grasshoppers when the experiment was initiated, the population quickly built up in the untreated plots in a week. In this experiment, parathion was the most effective material tested for grasshopper control. There appeared to be no significant differences in the susceptibility of the various species of grasshoppers to the several toxicants which proved to be effective.

A small population of tarnished plant bugs in this experiment made it difficult to evaluate the various materials tested.

Table 2.—Summary of 75 net sweeps showing the control of several species of insects of red clover with four different organic insecticides applied with a power duster July 15 at Fulton, New York.

Treatment	Dust Applied per Acre in Pounds	Grasshoppers	*Lygus oblineatus*	*Philaneus leucophthalmus*	*Philaneus lineatus*	*Macrostoles divisus*	*Empoasca fabae*	*Sitona flavescens*	*S. cylindricollis*	*Hypera meles*	*H. punctata*	Aphids	*Tychius* spp.	Total
48 Hours After Treatment														
Chlordane, 5%	45	0	4	5	3	0	0	1	1	0	0	0	2	16
TDE, 5%	45	0	3	3	3	0	0	2	0	1	0	4	5	21
Parathion, 1%	46	0	2	1	5	0	0	6	1	0	0	0	1	16
Benzene hexachloride,	45	0	0	1	0	0	0	31	2	0	0	0	4	38
Check	—	0	4	3	1	0	0	33	10	1	1	0	3	56
72 Hours After Treatment														
Chlordane, 5%	45	2	10	8	3	1	2	8	0	0	0	0	8	42
TDE, 5%	45	6	8	8	2	3	0	23	0	2	0	0	27	79
Parathion, 1%	46	0	4	10	2	1	1	1	0	0	0	0	1	20
Benzene hexachloride,	45	3	0	9	2	2	0	27	0	1	0	9	12	65
Check	—	11	13	12	5	0	1	17	0	0	0	6	17	82
1 Week After Treatment														
Chlordane. 5%	45	70	39	22	6	1	0	70	0	0	3	7	11	229
TDE, 5%	45	35	21	22	3	6	0	36	0	1	0	0	12	136
Parathion, 1%	46	7	13	25	2	3	0	4	0	0	4	1	4	63
Benzene hexachloride, 3% gamma	45	59	47	28	3	0	0	70	0	1	4	15	16	243
Check	—	81	24	19	6	5	0	57	0	0	2	4	7	205
2 Weeks After Treatment														
Chlordane, 5%	45	48	41	13	4	9	6	3	0	1	0	31	5	161
TDE, 5%	45	31	33	13	5	11	4	2	0	1	0	27	10	137
Parathion, 1%	46	11	62	17	4	11	2	1	0	3	0	12	4	127
Benzene hexachloride, 3% gamma	45	16	35	5	7	6	3	7	0	1	6	28	12	126
Check	—	123	54	17	7	12	2	4	0	2	1	46	13	281
3 Weeks After Treatment														
Chlordane, 5%	45	58	40	14	4	27	3	1	0	5	0	175	4	331
TDE, 5%	45	47	69	20	11	28	6	3	0	2	0	88	13	287
Parathion, 1%	46	51	34	32	7	25	9	1	0	2	0	21	3	185
Benzene hexachloride, 3% gamma	45	62	41	14	2	19	8	8	3	1	0	46	10	214
Check	—	62	93	16	5	14	4	8	1	2	0	145	12	362

However, both parathion and benzene hexachloride gave promising immediate protection but no insecticide persisted in its toxicity more than one week.

One per cent parathion at the rate of 45 pounds of dust per acre was the most effective insecticide for the control of *Sitona flavescens*, *Tychius* spp. and the several species of aphids.

Infestations of potato leafhopper, six-spotted leafhopper spittlebugs, clover head weevil, and clover leaf weevil were too small to yield any significant results.

Interplot migration of insects between small plots in an experiment often confounds the results of various treatments. Therefore, an experiment using large unreplicated 1 acre block plots were designed on a pure stand of 2-year-old alfalfa at Bowens' Corners in Oswego County.

On July 21, four different insecticides, 5 per cent each of chlordane, DDT and TDE as well as 3 per cent gamma isomer of benzene hexachloride, were applied with the power duster primarily for the control of grasshoppers, aphids and *Lygus* bugs. It was also hoped that these materials might serve as a protectant against the potato leafhopper and alfalfa yellows.

Insect counts were made as in the other experiments. Twenty-five net sweeps were taken in three random areas 60 and 90 hours after treatment. Further insect counts were made at 7 and 20-day intervals after dust application.

As may be seen in table 3, excellent kills of grasshoppers were recorded with the use of chlordane and benzene hexachloride. These materials remained effective for 20 days or for the duration of the experiment. All the materials controlled 84 per cent or better of the aphids for a period of a week; however DDT was a little inferior to the other materials

Table 3.—Summary of 75 net sweeps showing the control of insects of alfalfa with four different organic insecticides applied with a power duster July 21 at Bowens' Corners, New York.

Treatment	Dust Applied per Acre in Pounds	Grasshoppers	*Lygus oblineatus*	*Philaneus leucophthalmus*	*Philaneus lineatus*	*Macrosteles divisus*	*Empoasca fabae*	*Silona flavescens*	*S. hirtipidula*	Aphids	*Tychius* spp.	Total
					60 Hours After Treatment							
DDT, 5%	40	74	3	3	0	0	0	0	0	0	0	80
Chlordane, 5%	45	0	1	0	0	0	0	0	1	0	0	2
TDE, 5%	45	34	2	0	0	0	0	0	2	1	0	39
Benzene hexachloride, 3% gamma	35	0	1	0	0	0	0	0	0	0	0	1
Check	—	101	15	14	4	0	0	1	4	50	1	190
					90 Hours After Treatment							
DDT, 5%	40	54	6	1	0	0	0	0	0	5	0	66
Chlordane, 5%	45	0	0	1	0	4	0	0	2	0	0	7
TDE, 5%	45	37	6	2	0	0	0	0	1	1	5	52
Benzene hexachloride, 3% gamma	35	0	0	2	0	1	0	0	0	0	1	4
Check	—	151	34	14	3	2	2	0	1	51	3	261
					7 Days After Treatment							
DDT, 5%	40	28	4	2	2	0	0	1	2	9	0	48
Chlordane, 5%	45	0	0	1	0	5	0	0	0	1	0	7
TDE, 5%	45	45	5	3	1	10	2	0	2	1	0	69
Benzene hexachloride, 3% gamma	35	1	0	3	0	0	0	0	0	0	0	4
Check	—	33	6	3	0	0	1	0	0	55	0	98
					20 Days After Treatment							
DDT, 5%	40	68	8	2	4	4	8	0	0	19	0	113
Chlordane, 5%	45	0	7	7	6	5	3	1	0	14	0	43
TDE, 5%	45	38	3	5	5	3	1	0	0	11	0	71
Benzene hexachloride, 3% gamma	35	4	2	3	2	5	3	1	1	0	1	22
Check	—	72	8	5	2	3	10	1	0	M	0	(101)

Table 4.—Summary of 75 net sweeps showing the control of insects of alfalfa with two piperony cyclonene formulations applied by helicopter August 10 at Skaneateles, New York.

Treatment	Dust Applied per Acre in Pounds (Approx.)	Grasshoppers	*Lygus oblineatus*	*Philaneus leucophthalmus*	*Philaneus lineatus*	*Macrosteles divisus*	*Empoasca fabae*	*S. cylindricollis*	Pea aphid	*Tychius* spp.	Total
					Pre-dust Count						
T-247[1]	40	182	28	58	12	2	2	2	74	0	361
T-316[1]	40	147	19	34	26	0	3	0	82	0	311
					72 Hours After Treatment						
T-247	40	46	4	40	25	0	0	0	64	0	179
T-316	40	19	8	14	7	0	0	0	40	0	88
Check	—	83	1	2	3	0	1	0	102	1	193
					5 Days After Treatment						
T-247	40	28	15	17	15	1	1	0	150	0	227
T-316	40	18	—	20	7	0	0	0	36	5	(86)
Check	—	58	18	26	18	3	0	0	87	0	210
					7 Days After Treatment						
T-247	40	54	6	34	21	0	6	3	240	0	364
T-316	40	88	4	24	21	0	8	5	210	0	360
Check	—	66	3	27	21	0	6	0	300	1	424
					9 Days After Treatment						
T-247	40	120	9	61	28	0	0	8	127	4	357
T-316	40	45	8	44	24	1	2	14	98	3	239
Check	—	215	11	30	19	0	0	23	83	0	381

[1] Piperonyl cyclonene formulations.

tested. All the insecticides were successful in reducing the population of tarnished plant bugs, but benzene hexachloride and chlordane in that order were the best materials tested. No estimate could be made in the reduction of alfalfa yellows as an epiphytotic infestation of potato leafhoppers failed to materialize.

Near Skaneateles in Cayuga County, a 20-acre field of 2-year old alfalfa was divided into three large blocks. Two of the blocks were treated on August 10 by a helicopter with two piperonyl cyclonene materials coded as T-316 and T-247. The dusts were applied at the rate of 40 to 50 pounds per acre. In order to avoid a residue on the hay that might be harmful to dairy cattle or animals being finished for slaughter, no chlorinated hydrocarbons were used in the experiment although they had proven highly successful in earlier tests for the control of forage insects.

The purpose of the experiment was to determine whether rotary-winged aircraft could be used successfully on alfalfa for the control of forage insects, especially grasshoppers, spittlebugs, lygus bugs, pea aphids and potato leafhopper and to determine if the alfalfa aftermath could be protected from alfalfa yellows.

Insect counts were made in a manner similar to the previous experiment except that a predusting insect count was made in all the plots. Sweepings were also made at 72-hour, 5-day and 7-day intervals after application of the insecticides. These results are summarized in table 4.

While both of the insecticides somewhat reduced the population of grasshoppers and pea aphids 72 hours after treatment, neither of the materials gave satisfactory control of the insect complex on the alfalfa aftermath. The population of potato leafhoppers failed to increase to epiphytotic levels in the untreated plots; hence no conclusions could be drawn as to the effectiveness of the materials in protecting alfalfa from yellows. The use of rotary-winged aircraft proved to be feasible for use on forage crops under New York conditions.

SUMMARY AND CONCLUSIONS.—In several preliminary field trials during 1948 conducted in Oswego and Cayuga Counties on the insects of alfalfa and red clover, it was found that *Sitona flavescens* and *Tychius* spp. could be effectively controlled by the use of 1 per cent parathion dust applied at the rate of about 45 pounds per acre. Five per cent chlordane, 1 per cent parathion, and 3 and 6 per cent gamma isomer of benzene hexachloride gave excellent control of grasshoppers in New York lasting for as long as 20 days. Pea and other aphids of alfalfa and red clover were significantly reduced for a period of two weeks by the use of 1 per cent parathion, 6 per cent gamma isomer of benzene hexachloride and 5 per cent DDT. Although adult spittlebugs, largely the two species *Philaenus leucophthalmus* and *P. lineatus*, were difficult to control, six per cent gamma isomer of benzene hexachloride, 1 per cent parathion and 5 per cent chlordane dusts all showed some promise for immediate kills but none showed any appreciable residual toxicity as the populations of the treated plots quickly increased in number to equal those of the untreated checks. Most of the insecticides which included 5 per cent DDT, 3 and 5 per cent TDE, 1 per cent parathion, 3 and 6 per cent gamma isomer of benzene hexachloride and 5 per cent chlordane gave good reductions of tarnished plant bugs and other *Lygus* bugs but none of them persisted in toxicity much over a week. Two piperonyl cyclonene compounds coded as T-316 and T-247, while giving some control of aphids and grasshoppers, were not satisfactory for use on insects of forage crops. Both compounds showed little residual toxicity.

While many other species of insects were present in the experimental plots, their infestations were too small to yield any significant figures.

Control of the Melon Aphid in Northern California

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The melon aphid, *Aphis gossypii* Glov., was extremely abundant and widespread in California during the 1949 season. In some areas very large and destructive populations were encountered, and large quantities of aphicides were used to combat the pest. The seriousness of the infestation afforded ample opportunity to evaluate the effectiveness of several insecticides in controlling the pest on many kinds of melons including canteloupe, honeydew, Persian, crenshaw, casaba and watermelon.

Most of the insecticide investigations were conducted at Patterson, Stanislaus County. The principal materials tested were two per cent parathion dust, one per cent tetraethyl pyrophosphate dust and nicotine dusts of several concentrations. Besides these materials, very limited experiments were conducted with 2.5 per cent dusts of aldrin and dieldrin. All insecticide applications were made with a ground power duster and at a rate of from 30 to 35 pounds per acre.

Aphid populations were determined on each survey by examining the undersurface of from 50 to 100 leaves per plot. The leaves were selected at random from the center of the plants or row and were segretated into three categories, according to the degree of infestation. In the first category were placed those leaves that were non-infested to lightly infested, in the second those that showed medium infestation, and the in third those that were heavily infested. This method of determining populations, although not exact was rapid and gave an approximation of the aphid situation.

No definite statement can be made concerning the effectiveness of aldrin and dieldrin against the melon aphid. Although they showed some promise, the data obtained were not conclusive. There was some evidence that both of these materials exhibited a residual action inasmuch as the aphid population increased rather slowly where they were applied. This occurred despite the fact that there was a constant migration of winged aphids into the experimental area. However, the real evaluation of aldrin and dieldrin in the melon aphid control program must await further experimentation on a more extensive scale.

Ample opportunity was afforded to study the comparative effectiveness of nicotine, parathion and tetraethyl pyrophosphate dusts against the melon aphid. Of these materials a 2-per cent parathion dust usually resulted in the highest initial kill and best control under the conditions of severe infestation as they existed at Patterson. Next in effectiveness was a 1-per cent tetraethyl pyrophosphate dust followed by a 4-per cent nicotine dust. However the best treatments rarely remained effective for more than 3 weeks. In many cases control was secured for a period of only a week or two.

When applied under satisfactory conditions, tetraethyl pyrophosphate and parathion resulted in almost a complete kill of the aphid, but the excellent initial control was frequently nullified by a heavy influx of winged aphids from adjacent severely infested melon fields.

Observations were made concerning the action of tetraethyl pyrophosphate, parathion, and nicotine upon the natural enemies of the aphid. It was found that both tetraethyl pyrophosphate and parathion adversely affected the predatory insects, and apparently exerted a greater influence upon ladybirds than upon syrphid flies. On the other hand nicotine seemed to have much less adverse effect upon the natural enemies.

The destruction of natural enemies of the aphid created a rather serious situation. Where the predator population was reduced to an extremely low level, even the best treatments were unable to hold for any considerable period of time due to the constant influx of migrating female aphids. With the environmental resistance greatly reduced, the winged migrants established new colonies with ease, and in many cases the population increased at an extremely rapid rate.

Numerous comparisons were made in fields treated with tetraethyl pyrophosphate and parathion. In practically every case the population increase was more rapid where tetraethyl pyrophosphate was

applied than where parathion was used. It is possible that parathion may have exerted some slight residual action, although the more probable explanation is that parathion usually resulted in the highest initial kill.

Hundreds of acres of melons were grown in the Patterson area and all of these were treated one or more times with tetraethyl pyrophosphate or parathion. It is felt that the mass use of these insecticides made it almost impossible to obtain satisfactory control of the melon aphid with nicotine dusts. In 1948 exceptionally good control of the aphid was obtained on several occasions where a 4-per cent nicotine dust was applied under favorable conditions. The control secured was better than that obtained with tetraethyl pyrophosphate. However, during the past season, these results could not be repeated. It appears that satisfactory control of the melon aphid cannot be expected where the aphid infestation is severe and there are few natural enemies. The results indicate that nicotine performs best where natural enemies of the aphid are not destroyed.

The problem created by migrating aphids is very serious, and in most cases it cannot be effectively combatted by the individual farmer. However, some evidence was obtained which indicated that considerable benefit might be derived through community action. The present experiments were conducted with a producer who grew more than 1000 acres of melons. It was found that the control secured in a particular field could be greatly improved if it was possible to delay treatment until an adjacent field in which harvest was just completed could be disked under. If this procedure was followed, an important source of migrating aphids was eliminated. In cases where an adjacent, heavily infested field was left or not destroyed until after treatment, the influx of winged aphids was usually so great as largely to nullify the effect of the application. Numerous cases were observed where dangerous populations were present the week following treatment where the above conditions prevailed.

In cases where it was impossible to destroy heavily infested fields, it was found that considerable benefit could be derived by first treating the fields to the windward side. Where this precaution was taken the problem created by migrating aphids was reduced considerably.

Factors that influenced the effectiveness of the several insecticides were studied. It was found that the aphids were more easily contacted with the dusts where the vine growth was sparse than where it was vigorous and dense. Although the kills obtained tended to be better where the vine growth was somewhat open, it was satisfactory in the most vigorous growing and vegetative fields if tetraethyl pyrophosphate and parathion were applied under favorable conditions. Best control resulted where treatments were made on calm, still days. Parathion could be applied over a wider range of weather conditions than could tetraethyl pyrophosphate. For example, the latter insecticide was not nearly as effective when applied to plants wet with dew. Spotty control resulted where plants were wet to the point of dripping, and within a week following treatment the aphid population frequently increased to a very destructive level. While heavy dews adversely affected the mortality of aphids, little evidence was obtained to indicate thay they lessened the kill of natural enemies. Such a situation certainly favors a rapid increase in the aphid population. Because it is not unusual to encounter heavy dews, the period over which tetraethyl pyrophosphate dusts can be applied is somewhat limited. In this regard it should be mentioned that the denseness of the vines is also a contributing factor, for where it is heavy a longer time is needed for them to dry out. Why dew should reduce the effectiveness of the dust is not known for a certainty, but it is probable that in the presence of moisture the tetraethyl pyrophosphate hydrolyzes before it has had an opportunity to produce a satisfactory kill of the aphid.

The stability of the dust is another matter that must be taken into consideration in selecting a tetraethyl pyrophosphate dust. Unless the proper carrier is selected tetraethyl pyrophosphate rapidly hydrolyzes. There are, however, commercial dust mixtures available in which little deterioration of the tetraethyl pyrophosphate occurs within a period of several weeks after they are prepared. Only such products should be used, be-

cause to approach satisfactory control practically all the aphids in a treated field must be killed.

EFFECT OF DDT APPLICATIONS UPON THE MELON APHID.—It has been generally recognized that applications of DDT to melons on many occasions have resulted in an increase in the aphid population. However, it is desirable that a program be developed in which DDT can be used because it is so effective against *Diabrotica undecimpunctata* Mann., *D. trivittata* (Mann.) and the "melon leafhopper," *Empoasca abrupta* De Long. All of these insects are very destructive to melons and if not controlled may greatly injure the crop. During 1948 and 1949 extensive investigations were conducted and it was found that under some conditions DDT can be applied without resulting in a severe loss from aphids. On numerous occasions the environmental balance was not adversely affected. It is certain, however, that the amount of DDT used should be held to a minimum and treatments should be properly and thoroughly applied so that both the *Diabrotica* beetles and the leafhopper are nearly eliminated from the field. However, in order to guard against complications, frequent applications of DDT to control these insects should be avoided. During the early stages of growth a material such as cryolite should be used to control *Diabrotica* beetles. Later when the leafhopper population develops to a level to justify control, an application of DDT can be made. It was found that 30 pounds of a 3-per cent dust or a spray containing approximately 2 pounds of 50 per cent wettable powder per acre will adequately control the leafhopper as well as any *Diabrotica* beetles present. Such a practice need not result in a serious dislocation of the environmental balance. During the 1949 season insect population trends were followed in a number of fields that received a DDT treatment. Subsequent to treatment in fields at Brentwood, Contra Costa County, and at Woodland, Yolo County, there was an increase in the aphid population, followed rather closely by an increase in the predator population. Although the aphid population showed evidence of becoming destructive the threat failed to develop because of the rapid rise in the predator population. The end result was almost perfect biological control. The important predators involved were ladybird beetles, green lacewings, and syrphid flies. Of these, ladybird beetles appeared to be the most important. The principal species involved was the convergent ladybird beetle, *Hippodamia convergens* Guerin. The predators were able to establish themselves in the fields rather shortly after the DDT was applied. For example, at Brentwood a 3-per cent DDT dust was applied on July 25 and yet 4 weeks later the predator population had risen to a sufficiently high level to indicate clearly that it was going to suppress the aphid population. In another week areas of heavy aphid infestations were nearly 100 per cent eliminated. Another example was encountered at Woodland where a melon field was treated with a DDT spray on July 27. No aphids were observed in a survey conducted on August 5, but a survey a week later revealed the beginning of an infestation, which gradually increased until September 2. At this time there were localized areas of severe infestation, but these spots were heavily populated with predators and the aphid population was practically destroyed within the next 10 days. The above illustrations clearly demonstrate that predators are able to establish themselves in a field within a relatively short time after it has been treated with DDT. This was particularly true in regard to the field at Brentwood where four weeks after treatment it was evident that predators were going to control the aphid.

The rapid rate at which the predator population increases under favorable conditions is truly remarkable, and if the host population has reached a fairly high level just before it is suppressed the predators are present in great abundance. However, once the aphid is controlled there is a tendency for a rapid dispersal of the predators, and they largely leave the field. The period necessary to complete the cycle may last for only a few weeks. Where it is evident that natural enemies are in a position to control the aphid, applications of insecticides that are likely to destroy the balance should be avoided, if this is at all possible.

SUMMARY AND CONCLUSIONS.—The melon aphid is one of the most important pests of melons, and it usually becomes

more serious as the season advances.

Extensive investigations with insecticides have been undertaken. Some of the newer materials such as aldrin and dieldrin have shown some promise but any definite statement concerning their effectiveness must await further testing.

Parathion has proved to be the most effective where 4 per cent nicotine, 1 per cent tetraethyl pyrophosphate and 2 per cent parathion dusts have been compared. However, certain facts must be taken into consideration before any conclusions concerning comparative effectiveness can be drawn. In the area where the major portion of the insecticide investigations was conducted, there was a very large planting of melons and the aphid infestation was extremely heavy. Practically the entire acreage was treated with either parathion or tetraethyl pyrophosphate. Both of these insecticides are very destructive to natural enemies of the aphid, and this exerted an adverse influence upon the effectiveness of the nicotine treatments. Sastisfactory control with nicotine is dependent to a large extent upon natural enemies destroying the aphids that escape treatment. Therefore, in areas where the natural enemies are largely killed off by other insecticides the application of a nicotine dust is likely to result in poor control. The present studies indicate that treatments with the latter, following applications of organic phosphate insecticides or in areas where these materials are largely used, is likely to result in poor control and cannot be safely recommended. However, satisfactory control with nicotine has been obtained where it has been applied under favorable weather conditions and where the environmental balance has not been greatly altered by other insecticides.

Parathion proved to be the most effective in numerous experiments where a 2 per cent dust was compared with a 1 per cent tetraethyl pyrophosphate dust. The former was also effective over a wider range of weather conditions. Poor control with tetraethyl pyrophosphate but not with parathion resulted when these insecticides were applied to plants wet with dew.

The problem of migrating aphids is extremely important in areas where a serious aphid situation is present and where there is a large acreage of melons. It is possible that the use of organic phosphate insecticides may add to the problem. Satisfactory control of the aphid under such conditions is difficult. Some benefit will result if treatment of a field can be delayed until after a nearby field in which harvest is completed is disked under. Also, some value will be derived by first treating the fields to the windward side. In this connection most good would be derived through community action.

It is clear from the investigation that the demonstration of a good initial kill of the aphid is not sufficient. There are other factors that must be considered in the development of a satisfactory control program.

Studies to date have shown that with carefully timed applications, it is possible to use a 3 per cent DDT dust at 30 pounds per acre, or its equivalent as a spray to control *Diabrotica* beetles and leafhoppers without seriously interfering with the natural balance as far as the melon aphid is concerned. Numerous cases have been observed where the aphid has been satisfactorily controlled by predators following such treatments.[1]

[1] *Acknowledgments.*—Thanks are due to the following growers for their full cooperation in furnishing plots, equipment and materials: O. G. Olson and Herman Wood of Patterson, and Burnel Harlan and T. Dumars of Woodland.

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Herman S. Mayeux of Glenmora, Louisiana, former extension entomologist of Texas A & M College, who was located in the Lower Rio Grande Valley has been appointed technical adviser on all products and product development work for the Florida Agricultural Supply Company of Jacksonville, a division of the Wilson & Toomer Fertilizer Company.

The Walnut Aphid in Northern California

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The walnut aphid, *Chromaphis juglandicola* (Kaltenbach), is one of the most destructive insect pests of English walnuts in northern California. It is a pale yellowish species that frequently occurs in great abundance on the undersides of the leaves. The pest overwinters as eggs which hatch into stem mothers as soon as the new growth starts to push in the spring. During the growing season there are many generations of parthenogenetic forms, although beginning in June a few sexual males and females may be encountered. In late fall the sexual forms appear in numbers, and following mating the females lay the overwintering eggs. These are somewhat cigar shaped, black, and are usually found in greatest abundance about leaf and growth scars. During some years, overwintering eggs are difficult to find while in others they are encountered in large numbers.

The aphid injures walnuts in two ways. In the first place, when present in abundance, they reduce the vigor of the tree by their feeding, and, in the case of severe infestations, they cause leaves to drop and reduce the quality of the nuts. The second type of damage is secondary in nature, and is directly associated with the large quantities of honeydew secreted by the aphid. The honeydew drops on the leaves and the developing nuts and forms an excellent substratum on which a sooty mold fungus grows. The fungus results in a smutting of the leaves and nuts and where this dark surface occurs on walnuts exposed to the hot rays of the sun, the walnuts are severely sunburned, and their value is greatly reduced or destroyed.

The walnut aphid is an ever present pest, and since the investigation was undertaken in 1942 there has not been a single year when it has not at some time or another become abundant in all orchards under observation. The pest has a very high reproductive potential, and if it were not for its many natural enemies the problem of control would be much more difficult than it now is.

Most of the investigations concerning the walnut aphid have been conducted on the Payne variety in conjunction with control studies of the codling moth. The work has been principally centered in the Linden area in San Joaquin County, although investigations have also been carried on in the Santa Clara and Sacramento Valleys.

Population Determination.—In order to follow seasonal population trends and to compare treatments, it was necessary to use a standard means of evaluating aphid populations. It was found that this could best be accomplished by counting all the aphids that occurred on the underside of the next to the terminal leaflet of a walnut leaf. The leaflets for examination were gathered at random about the skirt of the tree. Because of the normally wide variation in the distribution of the aphid population, even on the same tree, no less than 50 leaflets were examined per treatment on any particular survey. In cases where plots ranged upward to 20 acres in extent, the aphids were counted on as many as 500 leaflets.

Throughout this paper the aphid populations are expressed in terms of the average number of individuals encountered on the next to the terminal leaflet.

Normal Seasonal Aphid Population Trends.—Because most orchards receive some kind of insecticide treatment, it is difficult to find one where the aphid can be studied in the absence of an insect control program. However, in 1947, investigations were conducted in such an orchard near Gridley in the Sacramento Valley. The seasonal aphid population trend is shown in figure 1. It should be noted that the aphid population reached two definite peaks that threatened serious damage, but that in each case the population rapidly declined. The trend of the population can be closely correlated with the abundance of natural enemies and certain other environmental conditions. The walnut aphid has many predators, and among the important ones are several species of lady bird beetles, lacewings, and syrphid flies. Of the ladybird beetles an ash-gray ladybird, *Olla abdominalis* (Say), the convergent ladybird, *Hippo-*

damia convergens Guerin, and on occasions *Stethorus picipes* Casey, are extremely important in reducing the aphid population. In conducting surveys the relationship that exists between the aphid and its natural enemies is closely followed. It has been observed that the balance between the aphid and its predators exhibits violent fluctuations. When conditions favor the aphid they increase rapidly. This is usually followed by a slow increase in the predator population, which soon gains momentum, and in a short time becomes sufficiently abundant to reduce the aphid population. As the aphid population declines, a point is reached where there is a large excess of predators. This population in turn is soon greatly reduced due to migration, cannibalism, parasitism, and to other factors not fully understood. The predator population may sink to such a low level that the balance again favors the aphid. This results in a rapid increase in the pest population from the few aphids that escaped the predators or from winged migrants or both. The rise in the aphid population is again followed by an increase in natural enemies and another cycle is well under way, so that in untreated orchards, the seasonal aphid population trends follow closely that shown in figure 1. However, additional observations indicate that the time the aphid population reaches peaks undoubtedly shows considerable variation in different years and in different orchards. Further, it is possible that under some natural conditions there may only be a single peak while under others there may be three. Although the aphid population as shown in figure 1 was large, it is interesting to note that apparently the quality of the nut crop was not seriously affected.

Although weather conditions must have some influence upon the aphid population no direct effect could be detected. It has been generally believed that periods of hot weather are unfavorable for the pest, but no observations were made that would indicate this was the case. The aphid population trend under natural conditions could always be more easily correlated with the abundance of natural enemies than with any other condition or factor.

In applying control measures it is important to know something concerning the seasonal population trend, and the importance of this in relation to the proper timing of insecticide applications is considered in a following section.

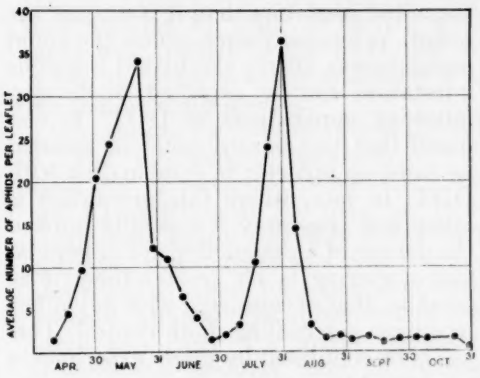

FIG. 1.—Seasonal aphid population trend in an untreated orchard at Gridley.

EFFECT OF CODLING MOTH SPRAYS UPON THE WALNUT APHID.—Investigations have shown that the insecticides used in the codling moth spray control programs may have a marked influence upon the walnut aphid. This was clearly demonstrated when DDT was first used for the control of the codling moth on walnuts in 1944. Although it resulted in an initial kill of the aphid, the application was followed by a marked increase in the population. For example, where a double spray of DDT was applied the average number of aphids per leaflet reached a peak of 239 as compared to 81 for unsprayed trees. The results obtained in this early investigation have been reported by Michelbacher *et al.* (1945). In 1945 DDT was further studied, and it was found to be effective in killing the aphid when used at the rate of one pound of actual material per 100 gallons of spray, but to insure satisfactory control it was necessary that the spray be thoroughly applied. If this was neglected a severe aphid infestation was almost certain to develop as reported by Michelbacher *et al.* (1946). One of the principal reasons for the development of destructive aphid populations is the fact that DDT seriously affects the relationship between the aphid and its natural enemies. There are probably other factors involved, but these are not so well understood. The investigations conducted have clearly shown that the residual action of DDT is more effective against some of

the aphid predators than it is against the aphid. As a consequence, unless the aphid population is nearly eliminated a serious infestation can be expected to develop following applications of DDT. It was found that this hazard could be avoided by using an aphicide in combination with DDT. In fact, where this precaution is taken and the spray is carefully applied the danger of a destructive aphid population occurring is no greater than, if as great as, that encountered with any other treatment for codling moth control. This has been confirmed by many experiments conducted to date.

Large aphid populations have resulted where methoxychlor has been used to control the codling moth. Where this insecticide was used in a commercial application, the aphid population increased to an extremely destructive level. The average number of aphids per leaflet reached a peak of more than 100 and the amount of honeydew excreted was so great that the trees appeared as if they had been sprayed with a syrup solution. The loss encountered in both yield and quality was considerable. The results of the experiment have been reported upon by Michelbacher *et al.* (1947).

Some evidence has also been obtained that would indicate that basic lead or standard lead arsenate sprays used for the control of the codling moth also favor a build-up in the aphid population. Although the increase in population is not as spectacular as that which occurs with some of the chlorinated hydrocarbon insecticides, it usually can be detected. This relationship was first noted in 1945, and was reported upon by Michelbacher *et al.* (1946).

INCORPORATION OF APHICIDES WITH THE CODLING MOTH SPRAY.—With the Payne variety of walnut it is usually a desirable practice in a number of localities to apply a spray during the early part of May to control the codling moth. Usually at about this time or a little later the aphid population increases to a dangerous level, and often control measures are urgently needed. In order to meet this situation the feasibility of adding aphicides to the codling moth spray has been extensively investigated beginning in 1947 and continued up to the present time.

The aphicides investigated were: 14 per cent nicotine dry concentrate, benzene hexachloride wettable powder, tetraethyl pyrophosphate, and 25 per cent parathion wettable powder. All these insecticides have been used experimentally for the past 3 years with the exception of parathion which has only been used for the last 2 years. The amounts used per 100 gallons of spray were as follows: 14 per cent nicotine dry concentrate, one pound; 20 per cent tetraethyl pyrophosphate, 0.25 pint; 25 per cent parathion, 0.33 pound; and benzene hexachloride containing 10 per cent gamma isomer 0.67 pounds. (In 1947 benzene hexachloride containing 6 per cent gamma isomer was used at the rate of 1 pound.) These aphicides were used in combination with codling moth sprays containing either 1 pound of 50 per cent wettable DDT powder, 3 pounds of standard lead arsenate, 4 pounds of basic lead arsenate or 3 pounds of standard lead arsenate, and 0.5 pound of 50 per cent wettable DDT powder to 100 gallons of spray. All spray mixtures contained 0.33 gallon of medium summer oil emulsion containing 83 per cent oil. In addition, 0.33 pound of a depositor was added to some of the mixtures, and most of the standard lead arsenate sprays were used in combination with 1 pound of a basic zinc sulfate safener.

Most of the experimental work was conducted in an orchard at Linden, in San Joaquin County. The sprays were applied to large trees planted at the rate of 17.4 trees per acre. All sprays were applied at a pressure of 600 pounds with conventional sprayers having 25-foot towers equipped for automatic spraying. In treating, the trees were completely encircled and approximately 55 gallons of spray were applied per tree.

All of the aphicides tested under the conditions of these experiments have resulted in excellent control of the aphid. As far as control is concerned, there appears to be little to choose between them. Satisfactory control was obtained when they were used in combination with the several insecticides used for the control of the codling moth. The results for 1947 and 1948 are summarized in table 1. Because the aphicides were about equally effective, no attempt has been made to show the control obtained with each

material. Instead the average control secured with the several aphicides in combination with the insecticides used for the control of the codling moth is given. It is seen from the table that in all cases the aphid population was reduced to a very low level and remained there for a period of 5 or more weeks. In 1947 check plots were not run in connection with the aphid plots, but in a portion of the orchard that received no aphicide the aphid population per leaflet on June 2 was 56 as compared to approximately 5 in the plots that were treated with aphicides in combination with the codling moth spray applied on May 2. The entire orchard was treated with a nicotine dust on June 12, which was applied under unfavorable conditions. This resulted in a reduction of the aphid population in the experimental plots. No further treatment was applied and although the aphid population rose to a rather high level in the treatments it was successfully reduced by predators.

In 1948 a check plot was run in conjunction with the treatments. The codling moth sprays were applied on May 10 and 11 at a time when the aphid population was very low. However, where aphicides were used the number of aphids per leaflet averaged less than one on June 10 as compared to an average of 43 aphids per leaflet where no aphicide was used. Because of this extremely large population, the check plot was treated with a nicotine dust on June 13, while no further treatment was applied to the plots that received the aphicides in combination with the codling moth sprays.

The results for 1949 are given in table 2. The information for each of the aphicides is recorded separately. The aphid population at the time the treatments were applied on May 4 was fairly large, but was reduced to a very low level and remained there for a period of about 5 weeks. Although the aphid control in all cases was good, the aphid population showed the greatest rate of increase where the nicotine dry concentrate and tetraethyl pyrophosphate were used in combination with the standard lead arsenate spray. The spread in the effectiveness of the aphicides was the greatest encountered in the 3 years that the investigation has been under way.

In addition to the work with conventional sprayers, investigations were also conducted during the past two seasons which showed that aphicides could be incorporated successfully with codling moth sprays applied with an air blast sprayer equipped with a volute. Excellent control was obtained with this machine where 14 per cent nicotine dry concentrate was used in conjunction with either standard lead arsenate or DDT. The control was particularly satisfactory where

Table 1.—Walnut aphid population trends where aphicides were combined with codling moth sprays at Linden.

Treatment	Average Number of Aphids per Leaflet on Survey Dates Given											
	1947[1]											
Spray and date applied	May 1	May 8	May 22	June 2	June 9	June 17	June 27	July 14	July 31	Aug. 19	Sept. 12	Oct. 21
DDT with aphicide May 2	6.7	0.00	0.3	5.7	5.8	4.0	21.5	39.7	1.8	5.7	9.5	0.5
Standard lead arsenate with aphicide May 2	6.3	0.00	0.6	5.0	14.0	6.5	35.7	6.3	1.0	4.1	27.3	0.6
Basic lead arsenate with aphicide May 2	3.1	0.03	0.8	3.4	5.3	1.6	13.3	3.8	1.0	6.5	25.2	1.3
	1948											
Spray and date applied	May 10	May 19	June 1	June 10	June 22	July 8	July 22	Aug. 2	Aug. 18	Sept. 7		
DDT with aphicide May 11	0.66	0.01	0.01	0.74	2.76	13.11	14.48	3.80	7.38	1.22		
Standard lead arsenate with aphicide May 10	0.23	0.00	0.02	0.26	3.29	28.84	9.82	2.40	4.72	0.01		
Standard lead arsenate *without* aphicide May 10	6.00	1.95	6.75	43.07	3.96[2]	6.06	6.08	6.75	5.81	—		

[1] Entire experimental area treated with a nicotine dust on June 12.
[2] Plot treated with a nicotine dust on June 13.

the following spray mixture was applied at the rate of 22 gallons per tree in the experimental orchard at Linden:

50 per cent wettable DDT powder	2 pounds.
Medium summer oil emulsion containing 83% oil	0.6 gallon.
Depositor	0.4 pound.
14 per cent nicotine dry concentrate	2 pounds.
Water	100 gallons.

AIR BLAST SPRAYER APPLICATION OF APHICIDES.—During the 1949 season extensive experiments were conducted to determine if aphicides could be applied effectively at a low volume with an air blast sprayer. The work was undertaken on June 10 at Linden when the aphid population in the experimental plots that had received pound of the 25 per cent wettable parathion to the acre. On June 10 when the treatments were applied, the average number of aphids per leaflet in the tetraethyl pyrophosphate plot was 20 while in the parathion plot it was 33.2. The results obtained are given in table 3. On June 13 three days after the aphicides were applied a comprehensive survey was made, and in neither treatment were any living aphids encountered. In a subsequent survey on June 21 an average of 0.1 aphid per leaflet was found in the tetraethyl pyrophosphate plot while in the parathion plot the count was 0.05. From here on the aphid population continued to increase and by August 1 the average number of

Table 2.—Walnut aphid population trends where aphicides were combined with codling moth sprays at Linden, 1949.

TREATMENT (Applied May 4)	AVERAGE NUMBER OF APHIDS PER LEAFLET ON SURVEY DATES GIVEN					
	April 27	May 4[1]	May 10	May 24	June 6	June 10
Standard lead arsenate, 14% dry nicotine concentrate	3.3	15.8	0.4	2.4	25.5	44.7
Standard lead arsenate, benzene hexachloride (10% gamma isomer)	4.3	16.8	0.0	0.1	5.0	16.3
Standard lead arsenate, tetraethyl pyrophosphate	4.6	13.1	0.4	3.5	29.4	31.4
Standard lead arsenate, parathion	8.8	15.8	0.0	0.2	6.2	18.4
Standard lead arsenate, DDT, 14% nicotine dry concentrate	—	9.0	0.2	1.0	7.5	8.3
DDT, 14% nicotine dry concentrate	4.3	11.4	0.1	0.6	3.7	16.8
DDT, benzene hexachloride (10% gamma isomer)	5.3	13.9	0.0	0.0	2.8	13.1

[1] Counts made prior to the application of the spray.

aphicides in the early codling moth spray had risen to a near dangerous level. (See table 2.) The entire experimental area of approximately 50 acres was divided into two equal plots. To one of these tetraethyl pyrophosphate was applied and to the other parathion.

The tetraethyl pyrophosphate was used at the rate of five pints of a 40 per cent material, and the parathion at the rate of 10 pounds of a 25 per cent material to 500 gallons of water. These mixtures were applied at approximately 50 gallons per acre. This is equivalent to 0.5 pint of the 40 per cent tetraethyl pyrophosphate or 1 aphids per leaflet in the tetraethyl pyrophosphate plot was 22.3, and in the parathion plot it was 16.5. The control obtained throughout, as seen from the data in table 3, slightly favored the parathion treatment.

On August 1 each of the two plots was treated for a second time, and a third plot was treated with a 14 per cent nicotine dry concentrate applied at the rate of 6 pounds in 50 gallons of water to the acre. The average number of aphids per leaflet in the nicotine plot prior to treating was 20. The results following the August 1 treatments are also given in table 3. On

August 3 no aphids were encountered in the plot treated with parathion, while an average of 0.02 were found per leaflet in the tetraethyl pyrophosphate treatment, and an average of 0.35 per leaflet in the nicotine dry concentrate treatment. The average number of aphids per leaflet on August 23 in the tetraethyl pyrophosphate, parathion, and nicotine plots was 0.9, 0.1, and 0.37 respectively. It is interesting to note that in the nicotine plot there was no increase in the aphid population over that encountered on August 3. This can probably be explained by the fact that the nicotine dry concentrate does not give as thorough a cleanup of predators as does the tetraethyl pyrophosphate and parathion. It, therefore, appears that following the nicotine treatment many predators escaped, and these were sufficient to hold the aphid population in check even though the initial aphid control was inferior to that obtained with tetraethyl pyrophosphate or parathion. Observations were made which actually indicated that this was the case. A final survey was made on September 7. The aphid population in the parathion treatment was much lower than that found in either of the other two treatments. The population in the tetraethyl pyrophosphate and nicotine treatments were nearly the same, although it was slightly lower where nicotine was applied.

Table 3.—Control of the walnut aphid where insecticides were applied with an air blast sprayer.

Treatment and Rate per Acre[1]	Average Number of Aphids per Leaflet on Survey Dates Given								
	June 10[2]	June 13	June 21	July 12	July 26	Aug. 1[2]	Aug. 3	Aug. 23	Sept. 7
½ pint, 40% TEPP in 50 gallons of water	20.0	0.0	0.10	1.3	13.4	22.3	0.02	0.90	17.6
1 pound 25% wettable parathion powder in 50 gallons of water	33.2	0.0	0.05	1.0	9.1	16.5	0.00	0.10	6.7
6 pounds 14% nicotine dry concentrate in 50 gallons of water	—	—	—	—	—	20.0	0.35	0.37	15.5

[1] First application June 10, second August 1.
[2] Counts made prior to application of insecticides.

Application of Tetraethyl Pyrophosphate with Commercial Smoke Generators.—In 1948 excellent control of the walnut aphid was obtained where tetraethyl pyrophosphate-diesel oil mixture was applied with a commercial smoke generating machine. Because of the promising results obtained, it was felt that this means of controlling the walnut aphid should be further studied in 1949, despite the fact that the method cannot be safely recommended for general use since there is no adequate means of controlling the smoke drift. A smoke generating machine was used exclusively for the control of the aphid in a large orchard near Linden. A tetraethyl pyrophosphate-diesel oil mixture was applied at a rate equivalent to approximately 0.5 pint of 40 per cent tetraethyl pyrophosphate per acre. The control obtained was excellent. A single application under favorable weather conditions resulted in a satisfactory control of the pest for a period of six or more weeks. In the orchard under investigation three applications during the season adequately controlled the pest for the season. The results approached that of the best aphid control programs so far investigated, but it is felt that the tetraethyl pyrophosphate smoke offers too great a hazard to warrant a general recommendation. Further, the full effect of the smoke upon birds and beneficial insects has as yet not been determined.

Application of Dusts for the Control of the Walnut Aphid.—The most common dust used to control the walnut aphid is a nicotine dust. When this material is carefully applied under ideal conditions excellent control can be expected. However, if the treatment is carelessly done or applied during periods of unsettled cool weather or with faulty equipment,

poor kills are frequently obtained, which necessitates retreatment in a short time. Such a practice should be avoided if at all possible because observations have been made which indicate that trees covered with an excessive amount of dust are more subject to serious attacks by orchard mites than are those which are covered with only moderate amounts of dust.

The timing of applications as reported by Michelbacher & Swanson (1945) is extremely important. Investigations have indicated that treatments should be applied before the aphid population reaches approximately 10 per leaflet. If treatment is much delayed it may do more harm than good because the host-predator population relationship may be so upset as to favor a rapid increase in the aphid population. Nature should be allowed to take its own course once the predator population reaches a level where it can overtake and reduce the aphid population. This condition is not likely to occur until the aphid population has risen to considerably more than 10 per leaflet. Therefore, treatment applied at about the time the aphid population reaches 10 appears to have the least adverse effect upon the host-predator relationship. In fact, some benefit may result because the treatment usually occurs at a time when the predator population is small. This may actually help in establishing a more favorable host-predator balance.

SUMMARY AND CONCLUSIONS.—The walnut aphid is one of the most destructive insects attacking walnuts in northern California. It is ever present and large populations can be expected every year.

It would be a much more troublesome pest if it were not for the fact that it is attacked by a large number of natural enemies. Of these, predators appear to be the most important and under natural conditions serve to keep the aphid population in check. Despite the effective work of the predators, there is a tendency for the aphid population to reach a dangerous level and control measures are justified. However, aphicides should be applied at a time when they will have the least adverse effect upon the host-predator balance. This is most likely at the time when there are approximately an average of 10 aphids per leaflet on an increasing population. Usually at this point the predator population is at a very low level, and the aphid population is on the threshold of a rapid expansion. If the application of an aphicide is delayed until the aphid population reaches a high level, there is every likelihood that the natural enemies are increasing at a rate that would soon reduce the aphid population, and the application at this time might do more harm than good.

Investigations have shown that the insecticides used for the control of the codling moth on walnuts have a tendency to increase the aphid problem, particularly materials such as DDT. Where the latter is used in the spray program it should be used in combination with an aphicide.

With the Payne variety it is usually a desirable practice to apply a spray during the first half of May to control the codling moth. After three years of investigation the results have definitely indicated that the addition of an aphicide to this spray is a desirable practice. The aphid is controlled at a time when insecticides appear to have the least adverse effect upon the host-predator balance. Further, the pest is controlled at a time that makes the application of a spring irrigation possible without the danger of a destructive aphid population developing while the orchard is under water. One pound of 14 per cent nicotine dry concentrate, or 0.67 pounds of benzene hexachloride containing 10 per cent gamma isomer, or 0.33 pound 25 per cent parathion wettable powder, or 0.25 pint of 20 per cent tetraethyl pyrophosphate per 100 gallons of spray all resulted in excellent control of the walnut aphid. However, satisfactory control can be assured only if the sprays are thoroughly applied.

No serious objections to the use of any of these aphicides have been encountered to date. Of the four, benzene hexachloride is the cheapest, but has one possible serious disadvantage and that is the danger of imparting an off flavor to the nuts. When used as in the present investigations no such flavor has been detected. However, where used by growers in a two spray program or later in the season an off flavor on occasions has occurred. Because of this benzene hexachloride will have to be used with considerable caution. Investigations are needed to determine

if there is any danger of it accumulating in the soil over a period of years to a point where it will flavor the nuts even though its use is restricted to a single treatment in early season. If its use should be limited because of an off flavor, there is the possibility that lindane can be used in its place, but this change would add considerably to the cost of the control program.

Based upon information obtained during 1949, it would appear that parathion should prove effective at a dosage of much less than 0.33 pound of 25 per cent wettable powder to the 100 gallons of spray. How much the dosage might be reduced still remains to be determined.

It is difficult to know just what aphicide should be recommended at the present time. The grower will have to make his own selection, but pending further investigations it would appear that the 14 per cent nicotine dry concentrate offers the least hazard. Properly applied this insecticide will give good control when applied with either a conventional sprayer or speed sprayer, and it is known to have the least adverse effect upon wildlife as well as on the natural enemies of the aphid.

From the results obtained, it appears that aphicides are more effective when used in combination with DDT than with standard lead arsenate.

For mid and late season control very good results were obtained where aphicides were applied with an air blast sprayer. The insecticides tested were 25 per cent wettable parathion powder, 40 per cent tetraethyl pyrophosphate, and 14 per cent nicotine dry concentrate. They were used at the following rates in 500 gallons of water: parathion, 10 pounds; 40 per cent tetraethyl pyrophosphate, 5 pints; 14 per cent nicotine dry concentrate 60 pounds. The diluted sprays were applied at approximately 50 gallons per acre with parathion resulting in the best control. The results obtained with tetraethyl pyrophosphate were good, although the dosage used was close to the minimum to insure satisfactory control. Where the rate of application dropped much below 50 gallons per acre some aphids escaped the treatment. Because it is difficult to maintain a constant application of 50 gallons per acre, it is believed that the amount of 40 per cent tetraethyl pyrophosphate should be increased from 0.5 to 0.67 pint per 50 gallons of spray. The initial kill obtained with the nicotine treatment did not equal that secured with parathion or tetraethyl pyrophosphate. However, many predators survived the treatment and these appeared to hold the pest in check so that in the end the nicotine appeared to produce a control at least equal to that obtained with tetraethyl pyrophosphate.

At the dosage used in the air blast sprayer applications, both parathion and tetraethyl pyrophosphate are very destructive to natural enemies of the aphid. Therefore, it is highly desirable that an exceptionally good kill of the aphid be obtained when these insecticides are used. Failure to accomplish this is very likely to result in a serious and rapid increase in the aphid population. Where the aphid control is nearly complete, predators will usually re-establish themeslves in the orchard by the time the aphid population begins to rapdily increase. Thus, if further artificial control is not applied against the aphids, the predators will be in a position to check the infestation before damage is done.

Although the results obtained with the air blast sprayer look very promising, further investigations are very much needed. To the present time the effect of parathion and tetraethyl pyrophosphate upon predators and parasites has not been adequately determined. Further, their effect upon birds and animals has not been ascertained. They have not been used for a sufficiently long period to insure that their continued use will not result in plant injury or in the increase of another pest, and until some of these problems are more fully understood commercial use of these materials should proceed with caution.

Exceptionally good control of the aphid was obtained where tetraethyl pyrophosphate was applied as a smoke aerosol. Despite this, it is considered too hazardous to warrant a general recommendation because there is no way of controlling the drift of the smoke.

Because of the extreme toxicity of tetraethyl pyrophosphate and parathion to human beings, these insecticides should be used and handled with caution. The precautions as given by the manufacturer should be carefully followed.[1]

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LITERATURE CITED

Michelbacher, A. E., and Clark Swanson. 1945. Factors influencing control of the walnut aphid JOUR. ECON. ENT. **38**(1): 127–8.

Michelbacher, A. E., Clark Swanson, and Gordon L. Smith. 1945. Effect of DDT on the walnut aphid in investigations with DDT in California, 1944. California Agr. Expt. Sta. Lithoprint. page 30.

Michelbacher, A. E , Gordon L. Smith, and Clark Swanson. 1946. Effect of codling moth sprays on the walnut aphid in investigations with DDT and other new insecticides in 1945. California Agr. Expt. Sta. Circ. **365**: 87–90.

Michelbacher, A E., W. W. Middlekauff, and Clark Swanson. 1947. Insect investigations on Payne. walnuts in San Joaquin County. Diamond Walnut News **29**(3): 8–11.

Factors Influencing Spray and Thermal Aerosol Application by Airplane

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The practical application of DDT in the form of a thermal aerosol has been carried out in control operations for larvae of *Anopheles quadrimaculatus* by the TVA for several years. This type of application produced by an airplane venturi exhaust generator (Krusé & Metcalf 1946) gives very satisfactory results under favorable meteorological conditions. The effectiveness is generally attributed to the large number of oil particles, wide swath distribution obtained, and the successful penetration by fine particles through vegetation (Hurlbut *et al.* 1947). An additional feature is that the dose is light enough to be used without seriously endangering wildlife organisms.

There are certain operating conditions, however, which are unfavorable for the most effective utilization of the thermal aerosol. These include higher flights (for purposes of safety, particularly in areas of uneven topography or other physical obstructions) and unfavorable thermal stratification of the air, both of which may result in excessive drift of the insecticide.

An increase in the particle size of the insecticide droplets appeared desirable to overcome in part these conditions of greater flight altitude and air movement. On the other hand, it was not known how great an influence such a change in particle size would have on penetration through vegetation, swath distribution and actual toxicity to the mosquito larvae. Certain aspects of this problem could be clarified by a comparison between an airplane exhaust generator and commonly-used spray nozzles. Such a comparison was possible on the same airplane equipment and appeared desirable to eliminate variables between types of equipment used.

The broad objectives of the study therefore included:

(1) Determination of a practical height of flight for application of a spray and a thermal aerosol for control of larvae of *Anopheles quadrimaculatus*.
(2) Determination of differences in insecticide deposit over a certain swath at different heights of flight.
(3) The effect of thermal stratification of air on deposition of sprays and aerosols.

MATERIALS AND METHODS.—A Consolidated Vultee BT-13, an all-metal low-winged monoplane, was equipped with

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[4] The authors wish to acknowledge the splendid cooperation of the pilots in the Transportation Section and the members of the Biology and Engineering Sections for their assistance in the work.

the thermal aerosol unit (Krusé & Metcalf 1946) and also with a spraying system using nozzles at five different locations on the craft, two at the wing tips, two at the stabilizer tips and one in the tip of the tail cone structure. A view of this equipment is presented in a publication by Hall & Hess (1947). The craft was equipped with a Pratt & Whitney 450 hp. motor with a constant speed governor regulating the motor at 1950 rpm. A cruising speed of approximately 120 mph. used during the experimental study gave a 24 acre treatment per minute, assuming a 100 foot swath, a reasonable swath for anopheline larvicidal treatment. The downdraft of the Vultee BT-13 is somewhat greater than that of the Stearman biplanes and considerably greater than that of the so-called "cub" type of airplanes.

The thermal aerosol unit was that described by Krusé & Metcalf. The particle output is actually a fine mist (principally 10 to 50 microns in diameter) instead of an aerosol, but the latter term has been in popular usage for the past several years. The spray, used comparatively, was discharged through five one-quarter TT 8002 nozzles (Chicago Spraying Systems) directed backwards. The median mass diameter was about 125 microns.

The pressure maintained upon the insecticidal solution for both types of discharge was accomplished by an electrically driven pump instead of the usual wind-driven propeller type. Liquid pressure of the spray was 70 pounds per square inch and for the aerosol 55 pounds per square inch to obtain a comparable output of spray material.

Since a comparison between the spray and the thermal aerosol was desired the discharge rate of each was adjusted to similar value. The measurement of this rate was carried out several times during the course of experimentation by collection of the output of the ground using the electric pump at the operating pressures. The respective discharge rates for the thermal aerosol and the spray were 1.385 and 1.37 gallons per minute or 0.11 lb. of DDT per acre for the standard 20 per cent DDT formulation. The contact of the solvent with the exhaust gases in the thermal aerosol unit causes some evaporation of the solvent and consequent increase in DDT content. This is estimated to result in a change from 20 per cent DDT to about 25 per cent DDT and would thus deposit about 0.13 lb. of DDT per acre by the aerosol.

The insecticidal comparisons for this study were all made with solutions of the toxin in a polymethylated naphthalene.[5] Although samples of this solvent vary in density, those used in this study weighed approximately 8.5 pounds per gallon or 1.02 grams per milliliter. Insecticides used at rates of 0.5 to 2.0 per cent in this solvent did not alter the weight significantly, but preparations containing 20 per cent DDT, the routinely used material, were considerably heavier, weighing 9.3 pounds per gallon or 1.12 grams per milliliter.

The sampling technique for insecticide deposits was essentially that described by Krusé & Metcalf. In practically all experiments 13 clean microscope slides were placed at 20-foot intervals over a 240 foot swath and dosage was computed on the basis of size determination of each particle present on the entire slide. The use of a dye technique (Yeomans 1949) using Duponol Red was carried out to a limited extent and found to be accurate and fairly rapid over the central swath area but impractical for the swath extremes, especially for the thermal aerosol deposits, since these small deposits were too far below the limits of the method.

All experimental studies were carried out during the inversion conditions which commonly exist shortly after dawn. Wind velocity was less than 1 mile per hour during the spraying operations. The aircraft was flown at right angles to the swath recovery slides regardless of slight wind drift.

Height of flight studies were carried out by using helium-filled balloons attached to strings of pre-determined lengths. The aircraft was flown immediately above the balloons. Temperatures were taken near the ground (6 inches to 1 foot) and at 5 or 6 feet to indicate inversion conditions. A brief discussion of the importance of inversion conditions which provides a downward air movement is given by Stierli & Schmitz (1949). On a number of occasions temperatures were taken at 5-foot intervals up to and including 25 feet using thermocouples attached to a potentiometer.

Experiments were carried out in two distinct areas, (1) a dewatered pond area some 30 to 50 feet below surrounding terrain near Wilson Dam, Alabama, and (2) a typical anopheline breeding area in Blackwell Swamp near Decatur, Alabama, with water depth of 2 or 3 feet. Most of the tests were carried out in the first area. Vegetation in this area was predominantly *Eleocharis macrostachya* which was cut and matted down in the treated area. The recovery slides were placed on flat pieces of roofing or thin boards about a foot square. Shrubs and trees surrounding the open area averaged 10 to 25 feet in height.

The larvicidal activity of the various applications, which is not dealt with completely in this paper, was tested in the following manner. A study area in Blackwell Swamp was selected which contained reasonably high larval counts and was amenable to airplane treatment at the desired levels of flight. At least 13 stations at 20 foot intervals were staked out in the water and uniform dipping procedures (Hess 1941) were used in a radial fashion surrounding each selected site less than 24 hours before treatment. The same procedure was used 12 to 24 hours after treatment. Just prior to the airplane treatment a paper plate was placed on the water at each site to hold one or two clean microscope slides. When dense vegetation was involved the plate was carefully worked through the plants and placed on the water surface with the plants being permitted to return to a position approximating normal. Larvicidal tests were also carried out in the drained area using insectary-reared larvae in paper plates.

RESULTS.—The degree of atomization is highly important in determining the pattern of deposit of a spray material discharged from an aircraft. The thermal aerosol and spray were compared with this difference in mind. It is evident from figure 1, however, that although there are many more large particles or droplets in a spray that there is always an abundance of smaller particles present, particularly at the edges of the swath. The presence of these smaller particles in a coarse spray material makes interpretation of results more difficult.

SPRAY VERSUS THERMAL AEROSOL.—A comparison of spray and thermal aerosol deposits at two different heights of flight was the first consideration in this study. These comparisons were made with a 20 per cent DDT solution[1] (approximate density 1.12 g/ml., or 9.3 pounds per gallon). At a height of 25 to 30 feet the spray deposition in the swath area studied was much greater than that of the thermal aerosol (Table 1). The difference was more pronounced in the central portion of the swath. The tendency for the smaller particles of the thermal aerosol to drift away from the area is indicated by the comparatively smaller deposit of the aerosol than the spray from a 50 foot height. The ratio of the amount of spray deposited to the thermal aerosol was 10:1 at a 30 foot height and 18:1 at a 50 foot height. Also apparent was the fact that a spray application from 50 feet deposited more DDT than the thermal aerosol from 25 feet. Although the spray produced a much greater peaking of material near the center of the line of flight the overall deposit over a 200 foot swath was still some eight times greater than the aerosol deposition.

In contrast to the striking differences in quantity of spray material deposited a consideration of the number of particles collected shows a similarity between the spray and the thermal aerosol, particularly at the lower levels of flight (25 to 30 feet). Figure 1, prepared from mean values of three different thermal aerosol and two different spray applications shows a maximum recovery of 125 particles from the aersol as compared to 98 for the spray at the lower level of flight. At the 50 foot flight these values dropped to 19 and 71, respectively, indicating a loss of about 86 per cent of the aerosol particles and about 19 per cent of the spray particles. The general spray pattern was fairly similar at both levels of flight while the aerosol recovery data indicate a somewhat similar pattern at the 25 to 30 foot height of flight. At 50 feet much of the aerosol output had been lost and the general recovery was more uniform with most particles being recovered away from the center of the line of flight. Slight air movement had a longer opportunity to act on the small particles and a dissimilar pattern of distribution occurred (Figs. 1 and 3).

[1] *Velsicol NR-70* as the solvent.

Table 1.—Spray-thermal aerosol deposits in milliliter of liquid per acre applied at the same rate at two heights in a single area. Density of liquid = 1.120 at 20° C.

Height	Center 100 Feet of Swath			Entire 200 Feet of Swath		
	Spray	Thermal Aerosol[1]	Ratio Spray/Thermal Aerosol	Spray	Thermal Aerosol[1]	Ratio Spray/Thermal Aerosol
25–30′	126.3	8.1	16:1	73.5	6.4	11:1
	48.2	4.5	11:1	25.2	3.3	8:1
	Av. 87.3	6.3	14:1	49.4	4.9	10:1
50′	85.1	3.2	27:1	49.7	2.5	20:1
	36.3	1.2	30:1	18.7	1.3	14:1
	Av. 61.2	2.2	28:1	34.2	1.9	18:1

[1] Each milliliter of spray contains 0.22 g. DDT, of thermal aerosol 0.28 g. DDT.

Particle size differences are strikingly shown in figure 1 with the heterogeneity of the spray particles being quite evident. Four or five mid-recovery stations show large particles which are primarily responsible for the heavy recovery deposits. At the edges of the swath the particle size is rather similar to the aerosol particles, showing that one is comparing droplets of like diameters in these portions of the swath.

SPRAYS.—The recovery pattern over a 200 foot swath is given in figure 2. Duplicate runs on two different mornings resulted in about a 30 per cent reduction of recovered material when the height of flight was increased from 25 to 50 feet (Table 1). Most of this difference seems to be due to fewer recovered particles (Fig. 1). Experimental flights made on different days at 35 feet did not produce markedly different results from those at 50 feet except a peak build-up of the deposit at one recovery station in the swath Indications were that satisfactory insecticide deposits could be obtained from sprays applied at 50 feet if inversion conditions were fairly good.

THERMAL AEROSOLS.—Differences between recoveries at 25, 35, and 50 feet indicate that over twice as much material was deposited at the lower level of flight even though meteorological conditions were practically ideal for the experimentation (Table 1). A deposit comparison between the amount in the central portion of the swath and the entire 200 foot swath showed no striking difference such as was evident with the spray. As one would expect the deposit from the aerosol became more uniform and considerably lighter at a 50-foot application, than at 25 to 30 feet (Fig. 3). Approximately one-third as much material was deposited at the higher flight. This is due entirely to greater recovery of numbers of particles, since the particle size settling into the study area was actually greater at the higher flight level.

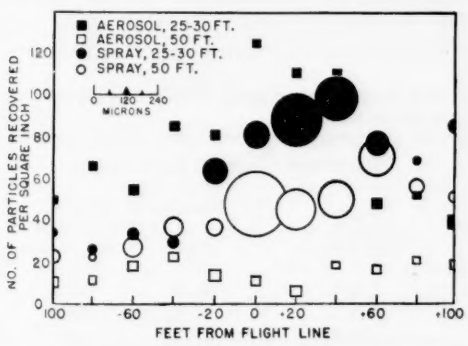

FIG. 1.—A comparison of mass median diameters and numbers of particles collected on subsidence slides in the flight swath at two different heights of flight involving spray and thermal aerosol discharge. Values are means of several flights using 20 per cent DDT in a polymethylated naphthalene (density 9.3 pounds per gallon).

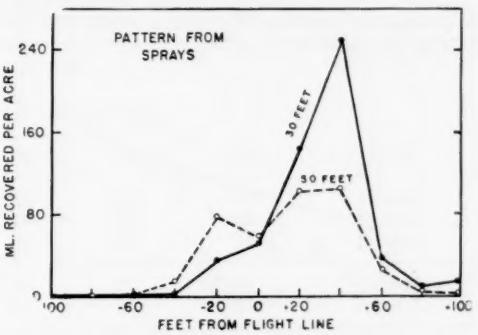

FIG. 2.—A comparison of duplicate sprays applied from a 30 and 50 foot height of flight, using 20 per cent DDT in a polymethylated naphthalene.

Table 2.—Spray-thermal aerosol deposits recovered using spray materials of 2 different densities applied in the same area on the same morning.

Type	Ht. of Flight	Density 20° C.	Recoveries in Ml. per Acre	
			Central	Entire
	(feet)	*(gm./ml.)*	*Swath*	*Swath*
Aerosol	25	1.12	4.5	3.3
Aerosol	35	1.02[1]	0.8	0.8
Aerosol	50	1.12	1.2	1.3
Spray	30	1.12	48.2	25.2
Spray	35	1.02[1]	42.5	21.7
Spray	50	1.12	36.3	18.7

[1] 0.5% chlordane.

Density of Spray.—The weight or density of particles was considered to a certain extent on several different applications. It was found that reduction of the concentration of DDT or chlordane in the solvent resulted in a lighter deposit of particles. A comparison of these deposits of materials of different density is given in table 2. These comparisons were made in the same area on a single morning. The results of the application by thermal aerosol show that a greater deposit of insecticide was actually obtained at 50 feet height of flight than at 35 feet provided the particles were heavier (almost 8 per cent heavier). Results with the spray were not as striking, since the particles, being larger, are not as subject to air movement. A trend is evident however, (Table 2) since the quantity deposited per acre was reduced from 25.2 to 21.7 or about a 14 per cent reduction with a difference of only 5 feet in altitude. Comparative results have been made within one area of experimental study, since different microclimatic conditions due to topographical differences do not permit accurate comparison of applications made in different areas.

Temperature Effect.—The effect of temperature upon deposit was of necessity studied on different mornings since it again appeared desirable to restrict the comparison to a single area (the drained pond area). Using material of the same density (1.12 g/ml.) nearly twice the amount of DDT was deposited on cooler mornings (60° F. as contrasted to 70° F.) (Table 3). Inversion conditions may have had some influence here, but the consistent results on several cooler mornings gave evidence of the importance of temperature. The heavier deposits of insecticide at lower temperatures is apparent at both heights of flight studied. In a single test the spray also produced a similar effect. Lower temperatures influence physical properties of an oil spray causing increased density, greater surface tension, and a higher viscosity of the oil resulting in heavier deposits (Webb 1946). Figure 4 pictures temperature and particle size relationships which indicate that the surface tension and viscosity factors act to produce larger particles under cooler air temperature. Greater density contributes some influence but density values are not markedly different, *e.g.* spray density was 1.128, 1.120, and 1.112 at 10°, 20° and 30° C. and this temperature range is greater than the temperatures encountered in the field. The increased surface tension and viscosity are possibly more important result-

Table 3.—Spray-thermal aerosol deposits recovered in a drained pond area, with temperature the only apparent variable. Material applied, 20° DDT in an oil solvent.[1]

Type	Ht.	Air Temp. (° C.)		Recovery over 240 Foot Swath		
				Amt./Acre Lbs. DDT	Number of Particles	
		6″	6′		Total	No. <30μ
Aerosol	25′	22	22	0.0016	96.8	89.5
Aerosol	25′	20	21	0.0020	26.8	16.8
Aerosol	25′	14	16	0.0039	87.1	60.6
Aerosol	50′	21	21	0.0008	18.5	14.7
Aerosol	50′	14	16	0.0015	13.2	6.6
Spray	50′	21	21	0.0092	13.7	6.4
Spray	50′	14	16	0.0244	76.9	59.8

[1] *Velsicol NR-70.*

Table 4.—A comparison of a 2% chlordane (wt. = 8.5 lbs. per gal.) thermal aerosol and spray application over water having low dense vegetation, using *Anopheles quadrimaculatus*. Recoveries of numbers of particles on the square inch basis.

	Swath Width Studied												
	−120	−100	−80	−60	−40	−20	C	+20	+40	+60	+80	+100	+120
Thermal Aerosol													
milliliters per acre	0.1	0.1	0.1	0.8	0.2	1.0	4.3	3.3	3.0	1.6	0.9	0.5	0.2
No. particles <30μ	1.0	0.3	3.0	4.0	10.7	10.0	46.3	38.3	18.3	12.7	10.7	8.7	6.7
per cent mortality	60	45	0	80	99	95	100	100	100	85	100	100	100
Spray													
milliliters per acre	3.3	2.0	2.3	27.2	24.3	16.5	33.2	88.2	96.5	28.8	0.1	0.1	0.1
No. particles <30μ	15.7	32.3	14.3	13.0	27.3	16.7	13.3	6.7	27.3	5.0	3.7	8.3	3.7
per cent mortality	95	100	100	100	100	100	100	100	100	100	80	80	52

ing in more large particles thus producing greater deposits of spray material.

LARVICIDAL CONTROL AND PARTICLE DETERMINATIONS.—A number of tests were carried out for control of the larvae of *Anopheles quadrimaculatus* using dosage and particle size determinations concurrently. It was necessary to reduce the insecticide concentration greatly to avoid complete mortality within the study area. One such comparison is given in Table 4. The somewhat unexpected relationship here is the fact that there are as many or more small particles of the spray (*i.e.*, particles < 30 microns diameter) than of the aerosol, therefore any effect of dense vegetation on stopping spray particles is greatly minimized assuming that small particles penetrate vegetation more easily (Hurlbut *et al.*, 1947).

CONCLUSIONS.—The importance of particle size or droplet size has long been recognized in connection with airplane application. Numerous articles have dealt with this aspect of the problem (Brooks 1947; French, 1947; Wolfenbarger 1946; and many others). This is again apparent in the present study with the markedly heavier insecticidal deposit from a coarser spray as contrasted to the thermal aerosol output. The characteristics of smaller particles for the thermal aerosol make it possible to obtain a more uniform distribution swath, however, providing the deposit is adequate. For anopheline larvicidal control an application height of 50 feet makes adequate deposition in the desired area somewhat uncertain for the aerosol as compared to the spray. At 25, 30, or 35 feet an aerosol deposit can give very satisfactory larval kills providing meteorological conditions are favorable. A similar output or discharge of a spray results in a heavy dose being deposited near the center of the line of flight. This is due mainly to the large particles and not to the number of particles. This might be objectionable from the standpoint of harming other organisms.

An effort has been made in the present study to keep a number of factors reasonably constant. These factors have included the entire equipment, air stability involving wind velocity and direction, height of flight, and study sites. This has made it possible to obtain additional in-

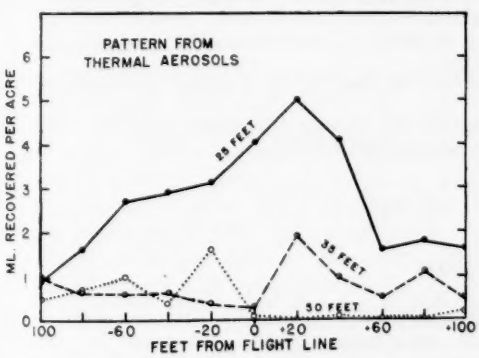

FIG. 3.—A comparison of single applications of thermal aerosols applied from 25, 35, and 50 foot height the same morning. The solution was 20 per cent DDT in a polymethylated naphthalene.

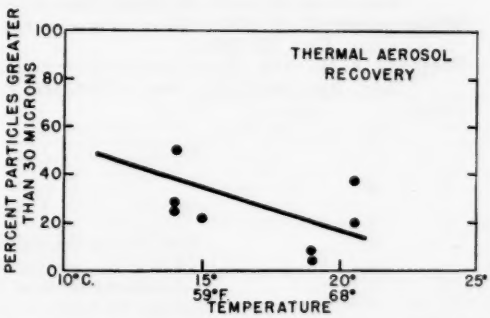

FIG. 4.—The influence of air temperature on particle sizes collected from thermal aerosol applications on different mornings.

formation on weight or density of the spray liquid and the effect of temperature upon spray deposition. A greater insecticidal deposit was obtained with heavier liquid spray. This was especially evident with the thermal aerosol, the median mass diameter of which was in the range of 35 microns. This influence is evident to a lesser degree in a spray containing medium-sized particles. This factor deserves further study.

The temperature effect was also quite noticeable in this study with a greater insecticide recovery at 60° than at 70° F. Additional experiments are desirable to indicate the importance of the temperature. The changes which take place involve the physical properties of the spray droplets. More larger particles collected at cooler temperatures are probably the result of greater surface tension and viscosity. Particles are also somewhat heavier (more dense). Here, also, additional study is needed.

The penetration of aerosol produced particles through vegetation to the water surface was evident, but a similar effect was obtained with small particles of the spray. This fact made it difficult to attribute any advantage of the aerosol as far as vegetation penetration was concerned since the spray contained heterogeneous particles, many of them being less than 30 microns in diameter.

SUMMARY.—A comparative study between thermal aerosol and common spray nozzle airplane application indicates that an effective higher flight (50 feet) is possible with the spray for larval control of *Anopheles quadrimaculatus*. Ordinarily, the aerosol could not be effectively used much above 35 feet. In addition to particle size the deposit and distribution of the thermal aerosol is influenced by the density of the spray liquid. The deposit is greater with a more dense liquid. Cool temperatures increase the deposit somewhat. Both of these factors, density and temperature, produce more pronounced effects when smaller particles are used as in the thermal aerosol than with coarse particles which are common in the output of the spray equipment.

LITERATURE CITED

Brooks, F. A. 1947. The drifting of poisonous dusts applied by airplanes and land rigs. Agricultural Engineering **28:** 233–9.

French, O. C. 1947. Use of the airplane for pest control. Agricultural Engineering **28:** 240–2, 244.

Hall, T. F. and Hess, A. D. 1947. Studies on the use of 2,4-D for the control of plants in a malaria control program. Jour. Nat'l. Malaria Soc. **6:** 99–116.

Hess, A. D. 1941. New limnological sampling equipment. Limnological Society of America, Special Pub. No. 6, April 1941.

Hurlbut, Herbert S., John D. Maple, Chas. S. Wilson, Stanley R. Fallander, and Chester N. Husman. 1947. Observations on the dispersal of DDT from aircraft for the control of mosquitoes. Naval Med. Bull. **47**(2): 368–79.

Kruse, C. W. and R. L. Metcalf. 1946. An analysis of the design and performance of airplane exhaust generators for the production of DDT aerosols for the control of *Anopheles quadrimaculatus*. U. S. Public Health Reports **61**(32): 1171–84.

Stierli, H. and W. R. Schmitz. 1949. The operation and physical evaluation of routine applications of DDT larvicides by airplane. Mosquito News **9:** 1–7.

Webb, J. E. 1947. A spraying apparatus and testing chamber for investigating the residual action of insecticidal deposits. Bull. Ent. Res. **38:** 209–32.

Wolfenbarger, D. O. 1946. Observations on the airplane for application of sprays and dusts. JOUR ECON. ENT. **39:** 503–5.

Yoemans, A. H. 1949. Directions for determining particle size of aerosols and fine sprays. U. S. Dept. Agr., Agr. Res. Adm. Bur. of Ent. and Plant Quarantine. **ET-267.**

CORRECTION

The North Central States Branch A.A.E.E. will hold its 1951 meeting on March 21–22 at the Commodore Perry Hotel at Toledo, Ohio, instead of East Lansing, Michigan as previously planned.

Habits, Rates of Infestation and Control of Woolly Apple Aphid in Nursery Plantings[1]

F. L. Gambrell and H. C. Young, Jr., *New York State Agricultural Experiment Station, Geneva, N. Y.*

During the past few years there has been a recurrence and definite increase in the abundance and in the severity of injury of the woolly apple aphid, *Eriosoma lanigerum* (Hausm.), in nursery plantings in western New York. Underhill & Cox (1938) have reported that this aphid "has been for many years a very injurious pest of apple trees in the nursery and of young trees in the orchard." In many instances DDT has been incorporated into the summer spray program for the control of apple leafhopper, *Empoasca fabae* (Harr.), and the tarnished plant bug, *Lygus oblineatus* (Say), and in New York nurseries some of the blocks of apples which have shown the highest infestations of woolly aphid have been those plantings in which summer sprays were applied.

This, of course, raises the question as to the possible effect of DDT upon the parasite *Aphelinus mali* (Hald.) which is known to attack the woolly apple aphid. Thus far, no definite data have been obtained in New York on the effect of DDT on the aphid parasite. Newcomer *et al.* (1946) report that in the Pacific Northwest where DDT has been widely used in commercial apple orchards there has been a significant increase in the woolly apple aphid population, particularly when 6 or 7 cover sprays containing DDT were applied. Likewise, the rate of aphid parasitism was lower where DDT was used than where trees were sprayed with lead arsenate.

Infestation and Nature of Injury —It is known that these aphids are quite likely to appear in the planting during the same season that the rootstocks (usually seedling apples) are planted. For example, in a 3-acre block of apple seedlings planted in the spring of 1948 an average of 38 per cent of the trees were infested above the ground level by June 27, 1948. In this same planting records taken 3 months later, September 2, showed that 29 per cent of the trees remained infested above the ground level (Table 1).

The sprays were applied to this block with a 4-row, boom-type power sprayer delivering spray at a pressure of 400 pounds to the square inch. Three nozzles, one overhead and one on either side, were directed on each row, and all rows were sprayed in both directions to provide better coverage.

Injury to the bark of the trunk and limbs caused by this insect has not been too serious; however, severe damage has occurred on the roots, and in many instances the smaller, weaker trees have shown the most injury. Trees whose roots have an appreciable amount of damage are discarded as being unfit for sale unless the injury can be eliminated by judicious pruning. A small per cent of hairy-root (5 to 9 per cent) has been found in some apple blocks, but has not necessarily been associated with woolly aphid injury on the same trees. Above-ground infestations frequently occur where the bark has been injured in some way, either accidentally or in the pruning of lateral shoots or of the seedling stem just above the variety bud. Generally speaking, colonies appear most commonly on the wood above ground during late summer and early fall, and a general movement of females and establishment of new colonies may be observed during this period. Aphids also may be found on the roots of apple trees at that time of the year.

In addition to the injury caused on the

Table 1.—The per cent of seedling apple trees infested with woolly apple aphid above the ground level, and the effect of one summer spray on control, 1948.

Treatment	Rate per 100 Gallons	Per Cent of Trees Infested	
		June	September
Benzene hexachloride (25% gamma), with liquid oil-base sticker[1]	1 lb.–1 pt.	60	0
Nicotine sulfate (40%) with liquid oil-base sticker[1]	1 qt.–1 lb.–1 pt.	24	0
Parathion (25%) with sulfonated alcohol resin spreader-sticker[2]	1 lb.–½ pt.	29	0
Check (no treatment)		38	29

[1] *Orthex*, manufactured by California Spray Chemical Co.
[2] *Dupont SS-3*, manufactured by E. I. du Pont de Nemours Co.

[1] Journal Paper No. 820, New York State Agricultural Experiment Station, Geneva, N. Y., March 10, 1950.

roots of seedlings and standard apple varieties, woolly aphids also may cause injury to the mother plants and rooted shoots of East Malling rootstocks. The aphids overwinter on the crown of such plants and may easily be transferred to new plantings when the rooted shoots are planted in the nursery row for budding. Infested seedling apple rootstocks also may prove to be a source of infestation in standard apple plantings.

VARIETAL RESISTANCE.—Underhill & Cox (1938) found in Virginia that of 20 varieties tested only Northern Spy and Early Harvest when grown on their roots displayed definite resistance to woolly apple aphid establishment and formation of galls on the roots. During 1949 records of infestations were obtained both below the union (seedling roots) and above the union (budded variety) on a 2-year-old apple block comprised of several varieties. It should be pointed out that this block of trees carried a heavy infestation of woolly apple aphid colonies during the summer and fall of 1948, for which no special treatments were made at the time. The following schedule of sprays was applied in 1949:

March 28—Sodium dinitro ortho cresylate (22%)[1] 2 qts./100 gals.
June 20—DDT 2 lbs. plus Ferbam 1.5 lbs./100 gals.
July 11—DDT 2 lbs. plus benzene hexachloride (6% gamma) 2 lbs./100 gals.
July 21—DDT 2 lbs. plus Bordeaux 1.5–9–100 gals.

It was observed (Table 2) that a very high per cent of the trees showed infestation on the roots at digging time in the fall of 1949. It also was noted that there was a high per cent of trees infested above the bud union on all varieties except Red Spy and Northern Spy. Of those varieties present in the block, R. I. Greening and Baldwin trees had the most colonies and the largest colonies; whereas Double Red Delicious, Early McIntosh, Roger's McIntosh and Cortland trees had numerous small colonies. Both Northern Spy and Red Spy had only a limited number of very small colonies present on the bark of the variety itself. On the contrary, some of the most severely injured roots were observed on those trees budded to the Spy varieties. The rates of infestation of the different varieties listed in table 2 prevailed following the series of treatments indicated above.

Table 2.—Woolly apple aphid—rates of infestation and degree of injury on several varieties of 2-year-old apples at the time of digging. Records of infestation below the union (on seedling roots) and above the union (on the budded variety) were obtained on the same trees. Dansville, N. Y., November 10, 1949.

VARIETY	PER CENT OF TREES INFESTED		PER CENT OF TREES UNSALABLE[1]	PER CENT OF TREES WITH HAIRY ROOT
	Below union	Above union		
Northern Spy	76.5	7.0	40.0	6.6
Red Spy	98.0	7.3	50.3	6.6
Double Red Delicious	86.8	54.0	39.1	5.5
Baldwin	95.6	55.1	38.8	5.3
Early McIntosh	99.0	67.1	49.3	6.6
Cortland	94.0	67.6	46.3	9.6
Roger's McIntosh	95.1	72.3	45.3	7.6
Rhode Island Greening	96.0	85.0	58.1	8.5

[1] These figures refer only to the number of trees discarded because of serious damage to the roots during gross examination in the field at digging time. Upon closer grading in the storage, further trees were discarded. The entire loss from this pest, considering all varieties, probably exceeded 50 per cent.

CONTROL.—Woolly aphid injury has been severe enough in many nursery plantings to justify the application of sprays for its control. Records obtained during 1948 (Table 1) indicated that one application of nicotine sulfate, parathion, or benzene hexachloride was very effective in reducing the number of above-ground colonies of the woolly aphid on apple seedlings. Further experiments were conducted during 1949 on 1-year-old apple trees. Randomized, buffered, single-row (approximately 75 trees) plots replicated four times were sprayed with a hand-gun delivering 3 gallons per minute at 300 pounds pressure. Six applications were made during the summer from May 27 through August 4.

The benzene hexachloride treatments (Table 3) were the most effective in the control of above-ground colonies, followed by parathion and nicotine sulfate. These same treatments will be continued on these plots during the summer of 1950 in order to determine the effect of treatments applied during two successive seasons upon the rate of infestation on the roots at digging time.

SUMMARY.—The woolly aphid is a serious pest of apple seedlings, East Malling rootstocks, and of budded varieties in the nursery. Loss at digging time may approach or even exceed 50 per cent of the trees of 2-year-old apples. Red Spy and Northern Spy varieties are much less susceptible to aphid infestation on the

[1] *Elgetol*, manufactured by Standard Agricultural Chemical Co.

Table 3.—The effect of summer spray treatments on the control of woolly apple aphid on 1-year-old McIntosh trees in a nursery planting. A total of 6 sprays were applied at 2-week intervals beginning May 27 and continuing through August 4, 1949.

Spray Material and Quantity per 100 Gallons	Total Trees	Per Cent[1] Infested
Benzene hexachloride (12% gamma)—2 lbs., liquid oil-base sticker[2]—1 pt., Glyoxalidine[3]—1.75 pt., spray lime—12 oz.	239	0
Benzene hexachloride (12% gamma)—2 lbs., liquid oil-base sticker[2]—1 pt., Fungicide[5]—24 oz.	234	2.6
Parathion (25%)—1 lb., sulfonated alcohol resin spreader sticker[4]—0.75 pt., Fungicide[5]—24 oz.	219	10.2
Parathion (25%)—1 lb., sulfonated alcohol resin spreader sticker[4]—0.25 pt., Glyoxalidine[3]—1.75 pt., spray lime—12 oz.	175	15.8
Nicotine sulfate (40%)—1 qt., spray lime—12 oz., Glyoxalidine[3]—1.75 pt.	149	22.7
Nicotine sulfate (40%)—1 qt., spray lime—1 lb., sulfonated alcohol resin spreader sticker[4]—0.25 pt., Fungicide[5]—24 oz.	248	24.2
Check (no spray applied)	235	63.5
L. S. D.—1 per cent point (99:1) 17.0%; 5 per cent point (19:1) 9.2%		

[1] Converted to degrees ($p = \sin^2 \theta$) for analysis.
[2] *Orthex*, manufactured by California Spray Chemical Co.
[3] *Crag Fruit Fungicide 341-C*, manufactured by Carbide and Carbon Chemicals Corp.
[4] *DuPont SS-3*, manufactured by E. I. du Pont de Nemours Co.
[5] *Ferbam*.

variety itself than are Bladwin, R. I. Greening, Cortland, Roger's McIntosh, Early McIntosh, and Double Red Delicious, but the roots of the seedlings on which the Spy varieties are budded may be as heavily infested as any other variety. Therefore, unless grown upon their own roots the loss of Red and Northern Spy varieties through unsalable trees may be as high as that of other varieties.

Benzene hexachloride (12 per cent gamma isomer) with a liquid oil-based sticker[1] mixed at the rate of 2 pounds of benzene hexachloride and 1 pint of sticker in 100 gallons has shown considerable promise for the control of this pest. Parathion and nicotine sulfate were somewhat less effective when applied under similar conditions.

The effect of DDT in the spray program upon parasites of the woolly aphid in the nursery planting has not been established, but whether DDT is included in the spray program or not, the use of benzene hexachloride on seedlings, 1, and 2-year-old apple trees for the control of the woolly apple aphid is indicated.

[1] *Orthex*, manufactured by California Spray Chemical Co.

Literature Cited

Newcomer, E. J., F. P. Dean, F. W. Carlson, 1946. Effect of DDT, Xanthone, and nicotine bentonite on the woolly apple aphid. Jour. Econ. Ent. **39**(5): 674.

Underhill, G. W., and J. A. Cox. 1938. Studies on the resistance of apple to woolly aphid, *Eriosoma lanigerum* (Hausm.). Jour. Econ. Ent. **31**(5): 622–5.

South African Entomologists

Mr. C. P. Lounsbury, of Pretoria, South Africa, to whom we are indebted for the following notes, said in a recent letter to Dr. Ernest N. Cory, that Charles K. Brain left the University of Stellenbosch about a score of years ago to take a non-entomological post with the Department of Agriculture, Salisbury, Southern Rhodesia. He retired from this some years ago and now lives at 61 Albert Street, Waterkloof, Pretoria, Waterkloof being a suburb not yet incorporated within the City of Pretoria. Relative to Rupert W. Jack, one time chief entomologist, Department of Agriculture, Salisbury, Southern Rhodesia, he was retired about 10 years ago and is now raising corn and tobacco about 20 or 30 miles west of Salisbury, which is about 675 miles from Pretoria by motor road. Richard H. Le Pelley is still with the Department of Agriculture, Nairobi, Kenya as senior entomologist, his address being P. O. Box 338, Nairobi. C. W. Mally still lives at "Ohiowa," Victoria Road, Stellenbosch, C. P., South Africa. He is retired. The name he gave to his house is a combination of Ohio and Iowa. He was born and raised in Iowa and lived and worked in Ohio before 1900 at which time he was induced by Mr. Lounsbury to join him in South Africa. The name Stellenbosch commemorates the surname of the Cape governor Simon van der Stel, who in 1680 settled the first white inhabitants there, with the presence on the site, of a bosch or grove of trees that had commanded the governor's admiration. Mossop, the Rhodesian chief entomologist, named his Salisbury residence "Llenroc," which is Cornell spelled backwards. Mossop studied at Cornell University and his wife was an Ithaca girl.

Codling Moth Infestation of the Tops of Apple Trees[1]

CHARLES H. RICHARDSON and F. ROBERT DU CHANOIS,[2] *Ames, Iowa*

It is rather generally recognized that control of the codling moth is more difficult to attain in the tops than in the lower parts of apple trees. This situation has often been attributed to poor spray coverage and poor maintenance of spray deposit on the fruit in the top branches. Several investigators have maintained, however, that the codling moth infests the fruit more heavily in the tops than in the lower parts, and that this habit of the moths, in addition to poor coverage and maintenance of spray deposit, accounts for the difficulty of controlling infestations in the tops of apple trees.

The published information pertinent to this subject has been derived from studies of orchards sprayed with lead arsenate or with some modification of the lead arsenate schedule involving nicotine, petroleum oil, etc., and antedates the general use of DDT for codling moth control. Furthermore, where information has been obtained from top and bottom tree levels, the records of infestation were taken at harvest, or at most, on one or two other dates prior to harvest. No fairly continuous seasonal record of top and bottom infestations has been found in the literature.

EXPERIMENTS IN DDT-SPRAYED ORCHARDS.—It seemed probable, therefore, that observations made at frequent intervals throughout the season in orchards sprayed with DDT might shed new light on this problem. Accordingly, two orchards, one at Mitchellville and the other at Ames, Iowa, were selected in the 1949 season for the experiments. Arrangements were made to sample fruit at random from the lowest branches to the 6-foot level (Richardson 1948) in the experimental sites of these orchards till the infestation in the lower parts of the trees reached 2 or 3 per cent. Then, a randomized plot design with 24 trees was established in each orchard and fruit in the top and lower branches of each tree was sampled simultaneously every 7 to 14 days for codling moth injury.

This program was carried out essentially as planned. The Mitchellville orchard received a calyx spray prior to May 24 and 6 cover sprays in the period from May 24 till August 25. Three of the cover sprays were applied before July first, the remaining 3 sprays in July and August. All these sprays contained, per 100 gallons, 2.12 to 3 pounds of DDT as the 50 per cent wettable powder; in addition, the third, fourth, and fifth sprays contained 0.75 pound of parathion (15 per cent wettable powder), the fourth and sixth sprays, one quart each of 25 per cent TDE emulsion, and the fifth spray 3 pounds of lead arsenate. (The parathion was intended particularly for mites, and the TDE and lead arsenate for red-banded leaf roller.) Wettable sulfur was added as fungicide to most of these sprays.

Most of the spraying at Mitchellville was done with an orchard sprayer equipped with guns and a 15-foot tower. Owing to a breakdown of this machine, a liquid duster was substituted during the second cover period (June 2 to 13). A part of the subsequent rapid growth of the codling moth infestation in this orchard may have resulted from this change in spraying apparatus.

The orchard at Ames received 6 sprays in the period from May 19 till August 12, 3 of the sprays before July first, and 3 sprays after that date. All sprays contained 50 per cent wettable DDT at 2 to 3 pounds per 100 gallons, and wettable sulfur as fungicide; in addition the fourth and sixth sprays contained 0.5 pound of parathion (15 per cent wettable powder). An orchard sprayer equipped with a spray boom was used throughout the season in this orchard.

The 24 sample trees in each orchard ranged from about 15 to 30 feet in height. Each tree was sampled in the top and on the lower sides 6 or 7 times during the season. A sample of 50 or 100 apples was examined from a ladder on each date in the sparse upright branches that projected above the general contour of each tree. As so defined, the top represents a smaller area than has sometimes been

[1] Journal Paper No. *J-1774* of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 1097.

[2] The generous aid of Mr. Robert M. Clark, Apple Grove Orchards, Mitchellville, Iowa, and of Professor Harvey L. Lantz, Department of Horticulture, Iowa State College, is acknowledged.

designated for other purposes as the top of an apple tree. An effort was made to score apples on the highest branches of each tree. At the same time, a sample of 50 or 100 apples (or 200 apples in some of the earlier counts) was examined in the lower sides of each tree (from the lowest branches to a height of about 6 feet).

The sampled fruit was scored without removal from the tree for the number of apples injured by codling moth larvae, and for the number of blemishes (worms, and/or stings) on each apple. The results are presented in table 1.

The figures show a marked difference in degree of infestation between the upper and lower parts of the trees on all dates of examination. Had such striking differences been expected, examination of the fruit in the tops would have started at an earlier date. There is no reason to believe, however, that this difference developed suddenly in July, but rather that it became established in the early part of the June period. Furthermore, it is difficult to believe that such differences in degree of infestation could develop so early entirely from faulty application of DDT or from weathering of DDT deposit, particularly when fresh spray deposits were being applied regularly in the June period. The values calculated for the June period on the basis of a 3:1 top/bottom ratio (Table 1) are believed to be conservative.

It is evident, then, that wide differences in degree of infestation between the tops and lower parts of trees may become established in DDT-sprayed orchards, and that these differences may appear early and persist throughout the season even when the sprays are closely timed.

DISCUSSION.—Support is found in the literature for the idea that poor spray coverage and maintenance of spray deposit in the tops of apple trees are responsible for the large differences in codling moth infestations in the tops and bottoms of the trees. Thus, Childs (1920) observed 1.8 to 5.0 times as much wormy fruit on trees above the 12-foot level as below that level, and noted in one tree which was sampled at the 0 to 12, 12 to 22, and 22 to 28-foot levels, 2.5 and 12.2 times as much wormy fruit at the second and third levels as at the first. This condition was attributed to lack of thorough spraying of the tops. Marshall & Ford (1933) found that worminess of fruit in sprayed trees was correlated with poor coverage in the tops as determined by chemical analysis of spray deposit. Top/bottom ratios of 0.9 to 2.8 (average about 1.7), based on worms per 100 apples, were calculated from their figures. The proportion of the tree area included in the tops was not stated. Ricks & Toenjes (1933) observed more wormy apples in the top halves of sprayed trees than in the bottom

Table 1.—Codling moth infestation in the tops and lower sides of DDT-sprayed apple trees, 1949.

LOCATION	DATE OF EXAMINATION	TOPS		LOWER SIDES		TOP/BOTTOM RATIOS	
		Blemished Fruit[1]	Blemishes[2]	Blemished Fruit[1]	Blemishes[2]	Blemished Fruit	Blemishes
Mitchellville, Iowa	May 25	—	—	0	—	—	—
	June 17	(2.4)[3]	—	0.8	—	(3.0)[3]	—
	July 7–8	19.8	24.0	1.8	2.0	11.0	12.0
	July 14	31.2	36.0	10.4	12.2	3.0	3.0
	July 26, 27	54.8	72.2	28.2	33.2	1.9	2.2
	Aug. 4, 5	54.7	71.1	27.8	34.4	2.0	2.1
	Aug. 15, 16	58.3	78.6	27.4	32.9	2.1	2.4
	Aug. 25[4]	53.5	73.2	17.2	21.2	3.1	3.4
Ames, Iowa	June 9, 10	(0.6)[3]	—	0.2	—	(3.0)[3]	—
	June 24	(3.6)[3]	(3.9)[3]	1.2	1.3	(3.0)[3]	(3.0)[3]
	July 6, 7	8.2	9.2	2.7	3.0	3.0	3.1
	July 11	11.4	12.9	2.3	2.6	5.0	5.0
	July 23, 25	17.5	20.1	5.0	5.5	3.5	3.7
	Aug. 1	22.4	26.9	6.5	7.5	3.4	3.6
	Aug. 11	31.6	40.0	7.5	8.1	4.2	4.9
	Aug. 22	40.2	51.8	8.7	9.3	4.6	5.6
	Sept. 1	45.4	68.0	9.5	10.5	4.8	6.5

[1] Average number of apples with worms and/or stings per 100 apples.
[2] Average number of worms and/or stings per 100 apples.
[3] Values estimated on basis of a minimum 3:1 top/bottom ratio.
[4] The lower values recorded on this date were the result of excessive dropping of the fruit.

halves; the top/bottom ratio for all orchards they examined in a 2-year period was 1.7. They regarded this difference as due to improper spray coverage in the top portion of the trees. Hansberry[1] investigated the distribution of codling moth infestation in sprayed trees and noted 1.3 times as much wormy fruit in the top halves as in the lower halves of these trees. No attempt was made to explain the cause of this distribution. Newcomer *et al.* (1943) obtained infestation data from sprayed trees 20 to 25 feet in height; the data, taken above and below the 10-foot level showed 1.9 to 7.3 times as many worms per 100 apples and an average of 1.2 times as many stings+worms per 100 apples in the upper parts as in the lower parts of these trees. Most of this difference was attributed to difference in thoroughness of spraying rather than to any inherent difference in the infestation. Woodside (1944) made a 2-year study of sprayed orchards in which records of codling moth infestation were taken at 6, 12, 18, and 24-foot tree levels. The ratios, based on the infestation at 6 feet, for each of the 2 years follows (infestation data for each level are computed as stings+worms per 100 apples): at 12 feet, 1.2 and 1.6; at 18 feet, 1.5 and 1.9; at 24 feet 1.9 and 2.9. Studies of the distribution of lead arsenate spray residues on the fruit of these trees showed 95 per cent greater deposit of arsenic and 52 per cent greater deposit of lead on fruit at the 6-foot level than on fruit in the topmost branches. Woodside emphasized the contribution of lower insecticide deposit in the tops to the heavier codling moth infestation of that portion of the trees; but he also recognized another factor, discussed below, as contributing to this difference in infestation.

A number of other investigators have observed differences in spray deposit on fruit from the top and bottom areas of apple trees. Several of these publications appear especially pertinent to this discussion. Weber *et al.* (1937) have discussed the redistribution of insecticides on sprayed trees which results from transfer of the materials from the tops to lower levels (see also Marshall & Ford (1933). Frear & Worthley (1937, 1937a) observed that growth of the fruit in the tops is considerably more rapid during most of the season than growth of fruit in the lower branches and state that in lead arsenate sprayed trees the loss of lead and arsenic is greater from the fruit in the tops, probably because of the greater weathering of spray deposit and the more rapid growth of the fruit in the tops.

Another factor on which some observations were made in Iowa during 1949 may be mentioned in this place. Many apples in the top branches were found to be smooth and polished, and it was observed that the fruit in the tops was often brushed and lashed by wind-blown foliage even at rather low wind velocities. It seems probable that the brushing action of the foliage may be a more important factor in the removal of spray deposit from fruit in the topmost branches than at lower tree levels.

Such other factors as the gravity runoff of spray liquid, chemical decomposition of spray deposit by heat, sunlight, and moisture, and by various inorganic and organic substances in solution have been discussed frequently in connection with the stability of spray deposits. No attempt is made here to review this rather extensive literature. It will suffice to say that many, if not most, of these factors will tend to minimize spray deposit in the tops and so will contribute to the development of large codling moth infestations in these locations.

A less extensive literature points, however, to the operation of another factor independent of the existence of spray deposit; namely, the preference by the moths for the tops of apple trees as a site for oviposition. Spuler (1927) noticed that "codling moths do most of their flying in tree tops. . . . This habit probably results in a higher percentage of eggs being laid in the upper portion of the trees and largely explains the wormy conditions usually found in tree tops, a condition heretofore entirely laid to faulty or careless spraying." Although now well established by bait trap records that the moths do fly more abundantly in the tops of the trees than at lower levels (see Woodside 1944), Spuler's statement lacked the crucial support of egg counts or of infestation records from unsprayed trees. Nevertheless this information is valuable in support of the evidence pre-

[1] Unpublished thesis, Iowa State College, 1936.

sented below. Egg counts were made in Indiana by Summerland & Steiner (1943), who found 3,581 codling moth eggs on marked bearing spurs of unsprayed apple trees, of which 57.3 per cent were deposited in the upper third of the trees and 42.7 per cent on branches within reach of the ground, a top/bottom egg ratio of 1.3. This ratio is within the range of some of the infestation ratios from sprayed trees already discussed, and within the range of the ratios from unsprayed trees given below. List & Newton (1921) examined at harvest the fruit of a single unsprayed Ben Davis tree in Colorado, and found 1.2 times as many blemished apples (stung+wormy fruits per 100) above the 12-foot level as below it. Woodside (1944) offers more extensive information on this point. His studies of two unsprayed orchards in Virginia showed that the infestation increased progressively with height above the 6-foot level just as it did in sprayed orchards. The ratios obtained by computing the data as stings+worms per 100 apples and using the 6-foot level as base were as follows: 12 feet 1.1; 18 feet 2.0; 24 feet 2.9. Woodside recognized that greater oviposition in the tops was a factor partially responsible for the heavier infestations of the topmost area.

The information discussed above is offered in support in the following hypothesis: *Preference by the codling moth for the tops of apple trees as a site for oviposition and faulty insecticidal spray coverage or poor maintenance of spray deposit lead to greater codling moth infestation in the tops than in the lower sides of the trees.* This hypothesis, which agrees essentially with the conclusions of Woodside, is intended (1) to apply to trees sprayed with lead arsenate, DDT, probably parathion, and possibly with other insecticides which are subject to marked deterioration by weathering and which do not have a pronounced ovicidal or repellent effect on the codling moth; (2) it applies throughout the season in which the codling moth is normally active; (3) it applies to trees 10 to 12 feet in height (and possibly lower), though it may be shown most strikingly by larger trees; (4) it applies when "top" is intended to designate the entire upper half of trees but is revealed in more striking fashion when comparisons are made between the extreme upper and lower parts of trees; (5) it applies to all parts of the United States (and probably to all other parts of the world) where apple trees, growing normally, are infested with the codling moth

SIGNIFICANCE OF EXCESSIVE TOP INFESTATION.—The existence of heavy codling moth infestations in the tops of trees ordinarily escapes notice because the extreme top branches, where the infestation is apparently heaviest, usually bear a rather small proportion, perhaps 10 per cent or less, of the total crop. Records of infestation are usually taken at harvest from samples drawn from the mixed crop of each tree. Trees with heavily-infested tops may therefore yield total crops in which the over-all infestation is light or moderate.

The greatest harm from excessive top infestations probably arises from the establishment of centers, early in the first brood period, from which moths may issue and spread the infestation over the orchard. These centers probably furnish a primary source of the sudden flare-ups of infestation which sometimes occur in orchards where the codling moth seemed to be well controlled.

The statement has been made that the population of overwintering codling moth larvae determines the size of each season's infestation. Normally, with the emergence of moths from pupae which have transformed from hibernating larvae, the population has reached its lowest point. Growth from that time forward is accelerated in the tree tops by selective oviposition and by the relatively smaller chance of poisoning by insecticides. The extent to which top infestations persist may become a factor of even greater importance in determining the population size of each season than the number of larvae that survive the winter.

CONTROL.—Removal of the high sparse growth, pruning to open up the trees and to lower the tops within effective reach of the spray are suggested means of controlling excessive top infestations; but more information, particularly from trees sprayed with the newer insecticides, would be desirable.

Removal of the fruit from the extreme top branches has also been suggested and might be profitable where the number of trees concerned is not large. This fruit will contain a large percentage of culls from mechanical as well as insect damage,

and will have small commercial value.

The value of new and improved spraying apparatus and of the newer insecticides in suppressing top infestations appears to have received relatively little experimental study based on actual determinations of infestation in the top branches. Such studies would seem to be important.

In conclusion it should be pointed out that although the second part of the proposed hypothesis—the contribution of faulty spray coverage and poor maintenance of spray deposit—seems proved beyond reasonable doubt, the first part—selective oviposition—rests on a much smaller amount of information. For this reason, it is the factor which should receive the greater immediate attention.

SUMMARY.—Experiments on codling moth control in two Iowa apple orchards sprayed with DDT during 1949 showed that the extreme tops of the trees carried during the period of observation about 2 to 5 times as much blemished fruit and about 2 to 6 times as many blemishes (stings+worms) per 100 apples as the fruit below the 6-foot level. It is believed this same condition prevailed throughout the entire season. The following hypothesis, based on the literature and the results of the experiments mentioned, is offered in explanation of this phenomenon: preference by the codling moth for the tops of apple trees as a site for oviposition and faulty spray coverage or imperfect maintenance of spray deposit lead to greater infestation in the tops than in the lower sides of the trees. This hypothesis applies (1) to apple trees sprayed with lead arsenate, DDT, and probably with other insecticides which deteriorate by weathering or are not strongly ovicidal or strongly repellent to the moths; (2) to the entire season of normal codling moth activity; (3) to trees 10 to 12 feet or more in height, (4) to the upper half of trees (but it is shown more strikingly by the extreme tops); (5) to all apple-growing regions of the United States. Heavy top infestations are often overlooked because the fruit from the tops is not segregated when infestation records are taken. Excessive top infestations act as centers from which the issuing moths may spread the infestation over the orchard. Top infestations may prove to be more important than the population of overwintering larvae in determining the size of a season's infestation. Control of top infestations is discussed briefly. The need of more information, based on studies of actual top infestations, on the following subjects is indicated: removal of high sparse tree growth; opening up the trees and lowering the tops within effective reach of sprays; removal of fruit from the tops; value of new spraying equipment and of new insecticides.

LITERATURE CITED

Childs, L. 1920. Spray gun versus rod and dust in apple orchard pest control. Oregon Agr. Expt. Sta. Bul. **171.**

Frear, D. E. H., and H. N. Worthley. 1937. The application of sprays to expanding plant surfaces. Science **85**: 610.

Frear, D. E. H., and H. N. Worthley. 1937a. Deposition and retention of sprays on apples. Penn. Agr. Expt. Sta. Bul. **344.**

List, G. M., and J. H. Newton. 1921. Codling moth control for certain sections of Colorado. Colo. Agr. Expt. Sta. Bul. **268.**

Marshall, G. E., and O. W. Ford. 1933. The relation of apple spray schedules to the arsenious oxide and lead residues. Indiana Agr. Expt. Sta. Bul. **381.**

Newcomer, E. J., F. P. Dean, and C. C. Cassil. 1943. Experimental methods in making orchard tests for codling moth control in the West. U. S. B.E.P.Q. **ET-215.**

Richardson, C. H. 1948. A system of sampling and rating codling moth infestations. JOUR. ECON. ENT. **41**: 75–9.

Ricks, G. L., and W. Toenjes. 1933. Success and failure in spraying for scab and codling moth. Michigan Agr. Expt. Sta. Special Bul. **230.**

Spuler, A. 1927. Codling moth traps. Wash. Agr. Expt. Sta. Bul. **214.**

Summerland, S. A., and L. F. Steiner. 1943. Codling moth oviposition and fate of eggs. JOUR. ECON. ENT. **36**: 72–5.

Weber, A. L., H. C. McLean, B. F. Driggers, and W. J. O'Neill. 1937. Influence of different materials on coverage and adhesiveness of sprays and their effect on residue removal from apples. New Jersey Agr. Expt. Sta. Bul. **627.**

Woodside, A. M. 1944. Codling-moth infestation at different heights in apple trees. Virginia Agr. Expt. Sta. Bul. **360.**

Plant Injury from Parathion and Related Compounds[1]

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Several cases of plant injury have been reported by users of technical-grade parathion. Since the problem of plant injury is of major importance to growers, a study has been made to determine what the injurious agents are. Tomatoes of three varieties and *Crassula multicava* were used as test plants.

Possible impurities in technical parathion that were investigated were 0-ethyl 0,0-bis(*p*-nitrophenyl) thiophosphate, *p*-nitrophenol, *o*-nitrophenol, and triethyl thiophosphate. In addition, the related compounds 0,0-diethyl 0-*p*-nitrophenyl phosphate (the oxygen analog of parathion) and 0,0-dimethyl 0-*p*-nitrophenyl thiophosphate (the methyl homolog of parathion) were investigated. Samples of pure parathion and its oxygen analog were prepared by the method of Edwards and Hall (1949).[2]

PREPARATION AND APPLICATION OF MATERIALS.—A 1-gram sample of each material was ground in a mortar with 4 grams of pyrophyllite to give a 20-per cent concentration, except in the case of *p*-nitrophenol and *o*-nitrophenol, which were made up at 5-per cent concentration. Crystalline materials were dissolved in twice their weight of acetone before being mixed with the pyrophyllite. Water containing 0.5 pint of 30-per cent decylbenzene sodium sulfonate[3] per 100 gallons was used to make a slurry in the mortar after the grinding and to dilute to the desired volume of completed spray. Concentrations given in the tables are exclusive of pyrophyllite. All applications were made with a small low-pressure paint sprayer until foliage was completely wetted but the spray did not run off.

Vigorous young tomato plants of the varieties Italian Salad, Globe Strain A, and Globe Wilt Resistant 3 growing in 3-inch pots were used in each treatment. Since all three varieties responded similarly, they are not considered separately in this report. Plants of *Crassula multicava* grown from cuttings were included in the experiments, because this species was found to be extremely susceptible to parathion aerosols.[4] The treated plants were grown in the greenhouse.

PLANT RESPONSE.—Injury to tomatoes was of two types, depending on the compounds used. The foliage of some of the treated plants developed water-soaked spots or marginal areas in a few hours, which changed to white bleached necrotic areas in 1 day. These spots did not increase in size with time. Other treated plants developed no immediate symptoms but in 3 to 4 days water-soaked areas developed on the older leaves. These areas gradually increased in size and became brown and necrotic. The surrounding areas gradually became yellow and died. Such plants with severely injured lower leaves developed weak, distorted, or rugose new leaves. The injuries were recorded as follows: severe, 50 to 100 per cent necrosis of older leaves or bleaching of young leaves; moderate, 10 to 50 per cent necrosis or bleaching; slight, few necrotic spots or light marginal leaf injury.

The injury to *Crassula* first appeared in 3 to 5 days, as water-soaked areas on the lower leaf surfaces and black necrosis at the base of leaves in the tender growing tips. The water-soaked areas soon became black and necrotic, epinasty of the stems occurred in 10 days, and the entire plant was dead in 10 to 14 days. Some of the plants were killed only to the ground, and weak new growth developed from below the soil.

As a preliminary experiment four samples of technical parathion, assaying from 67 to 95 per cent and supplied by various manufacturers, were tested. A sample of purified parathion was also included. The results are shown in table 1. The degree of injury to tomatoes appeared to be directly related to the impurity of the technical material, and at concentrations of less than 2 pounds per 100 gallons consisted entirely of the white, marginal

[1] Presented at the meeting of the Association of Economic Entomologists at Baltimore, Md., November 21–22, 1949.

[2] Samples of pure 0-ethyl, 0,0-bis(*p*-nitrophenyl) thiophosphate and triethyl thiophosphate were supplied by C. W. Gates of Naugatuck Chemicals, and samples of pure 0,0-dimethyl 0-*p*-nitrophenyl thiophosphate by S. A. Hall of this Bureau.

[3] *Santomerse.*

[4] Unpublished studies on plant tolerances by C. A. Thomas and Floyd F. Smith.

Table 1.—Plant response to foliage applications of pure and technical-grade parathion.

Sample and Per Cent of Parathion		Pounds of 100 Gal.	Plant Response	
			Tomatoes	*Crassula multicava*
Check (pyrophyllite)	—	—	None	None
Pure	100	2	Slight delayed necrosis	Necrosis; epinasty, death
		1	No delayed necrosis	
		0.5	No delayed necrosis	
Technical:				
No. 1	95	2	Slight delayed necrosis	Necrosis; epinasty, death
		1		
		0.5		
No. 2	93	2	Severe delayed necrosis	
		1	Slight delayed necrosis	
		0.5	Slight to no necrosis	
No. 3	68	2	Severe bleaching, death	Necrosis; epinasty, death
		1	Moderate bleaching	
		0.5	Slight bleaching	
No. 4	67	2	Severe bleaching, death	Necrosis; epinasty, death
		1	Moderate bleaching	
		0.5	Slight bleaching	

bleaching within 24 hours. Neither chromatographic separation nor filtering through fuller's earth removed the substance causing the injury. Various bands of a chromatographically separated sample[1] showed no difference in degree to type of injury. Filtering the technical material through fuller's earth removed some coloring matter and tars but did not affect the degree of injury. All the samples of technical parathion were injurious to *Crassula*.

One of the most common impurities in technical parathion is *p*-nitrophenol. Tests were made with pure parathion, pure *p*-nitrophenol, and mixtures of the two containing 2, 5, and 10 per cent of *p*-nitrophenol. Since *o*-nitrophenol also may occur as an impurity in parathion, it was also tested. The results are shown in table 2. As with the technical parathion (Table 1), the main injury to tomatoes was of the white marginal bleaching type and was directly related to the amount of free *p*-nitrophenol present. Pure *p*-nitrophenol did not injure *Crassula*, and *o*-nitrophenol did not injure either tomatoes or *Crassula*.

Tests were also run on two other impurities found in technical parathion, 0-ethyl 0,0-bis(*p*-nitrophenyl) thiophosphate and triethyl thiophosphate. Neither compound caused any injury to tomatoes at concentrations of 2 pounds per 100 gallons or less. The 0-ethyl0,0-bis (*p*-nitrophenyl) thiophosphate did not cause injury to *Crassula;* however, triethyl thiophosphate caused severe necrosis and

Table 2.—Plant response to foliage applications of pure parathion, *p*-nitrophenol, and *o*-nitrophenol.

Material Applied	Pounds per 100 Gal.	Plant Response,[2] Tomatoes
Parathion	2	Slight necrosis
	1	None
	0.5	None
Parathion 98% plus *p*-nitrophenol 2%	2	Slight necrosis
	1	None
	0.5	None
Parathion 95% plus *p*-nitrophenol 5%	2	Severe bleaching, slight necrosis
	1	Slight bleaching
	0.5	None
Parathion 90% plus *p*-nitrophenol 10%	2	Severe bleaching
	1	Moderate bleaching
	0.5	None
p-Nitrophenol[1]	0.33	Severe bleaching
	0.17	Moderate bleaching
	0.09	Slight bleaching
	0.04	None
o-Nitrophenol	0.33	None

[1] Used in concentrations approximating those present in a technical sample containing 10% of *p*-nitrophenol.

[2] *Crassula multicava* showed necrosis, epinasty and death from parathion and no response to *p*-nitrophenol or *o*-nitrophenol.

[1] Supplied by Plant Products, Inc.

Table 3.—Plant response to foliage applications of compounds related to parathion

Material and Pounds per 100 Gal.		Plant Response	
		Tomatoes	*Crassula multicava*
Oxygen analog of parathion	2	Severe bleaching, death	Necrosis; death
	1	Severe bleaching	
	0.5	Moderate bleaching	
Methyl homolog of parathion	2	Severe bleaching	Necrosis; death
	1	Moderate bleaching	
	0.5	Slight bleaching	Necrosis; plant recovered

death of the plants at the 2-pound dosage and moderate necrosis of the growing points and foliage at the 1-pound and 0.5-pound dosages. It was very much less injurious to *Crassula* than parathion.

Further tests were made with samples of purified 0,0-diethyl 0-*p*-nitrophenyl phosphate and 0,0-dimethyl 0-*p*-nitrophenyl thiophosphate. The results of these tests are shown in table 3. The 0,0-diethyl 0-*p*-nitrophenyl phosphate applied to tomatoes caused an immediate white marginal bleaching similar to that caused by *p*-nitrophenol. It also severely injured *Crassula*. This compound caused the most severe injury of both bleaching and necrosis on both plant species. The 0, 0-dimethyl 0-*p*-nitrophenyl thiophosphate caused the same over-all injury to both plant species that the oxygen analog did, although it was not so severe at comparable dosages.

CONCLUSIONS.—Tomato plants treated with high dosages of some technical-grade parathions suffer two kinds of injury, an immediate white marginal bleaching and a delayed necrotic spotting throughout the entire leaf surface. The immediate white marginal bleaching of tomato plants may be caused by *p*-nitrophenol (an impurity in technical parathion), 0,0-diethyl 0-*p*-nitrophenyl phosphate (oxygen analog of parathion), or 0,0-dimethyl 0-*p*-nitrophenyl thiophosphate (methyl homolog of parathion). The delayed, general necrotic spotting of tomato plants may be caused by parathion. In treating for pests, concentrations of more than 0.5 pound of parathion per 100 gallons of spray are rarely encountered. Injuries described in this paper did not occur or were very slight at this dosage level, where the better grades of commercial parathion were used.

The injury and death of *Crassula* may be caused by parathion or by its oxygen analog or methyl homolog.

0-Ethyl 0,0-bis (*p*-nitrophenyl) thiophosphate (an impurity in technical parathion) and *o*-nitrophenol (a possible contaminant of *p*-nitrophenol) do not injure either *Crassula* or tomatoes.

Triethyl thiophosphate (an impurity in technical parathion) does not injure tomatoes, and causes only slight injury to *Crassula*.

At comparable doses of the pure insecticides the order of toxicity to tomatoes is oxygen analog of parathion > methyl homolog of parathion > parathion. In toxicity to *Crassula* these compounds rank as follows: oxygen analog of parathion > parathion > methyl homolog of parathion. *p*-Nitrophenol is the impurity in technical parathion that is largely responsible for injury to tomatoes. In a series of parathions that were tested the *p*-nitrophenol content varied from 0.3 to 10.8 per cent. The majority of the samples contained 1.8 per cent or less, and did not cause the characteristic bleaching injury that followed similar applications of the less refined samples.

LITERATURE CITED

Edwards, F. I., and Hall, S. A., 1949. Purification of o,o-diethyl o-*p*-nitrophphenyl thiophosphate (parathion) for use as a primary standard. Anal. Chem. **21**: 1567.

Effect of Parathion on Immature Stages of Plum Curculio, Oriental Fruit Moth and Codling Moth within the Host Plant[1]

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In a previous paper[2] the writer and M. M. Darley presented data showing that benzene hexachloride and parathion were effective in killing the immature stages of the plum curculio in immature peaches. Additional observations and experiments were made in 1949 which show that parathion will kill larvae of the plum curculio, oriental fruit moth and codling moth after they gain entrance into the host plant.

Experiment 1.—A seedling block of peaches at the College Farm orchard at New Brunswick, N. J. was sprayed with parathion (1 pound 25 per cent wettable powder to 100 gallons of water) to control curculio and oriental fruit moth. The block of trees was made up of seedlings differing widely as to the date of blooming and huskfall. The first parathion application was made when the majority of the seedlings had three-fourths of the husks off. One very early seedling near woods which had the husks completely off and where curculio had been laying eggs for about a week was selected and a large bouquet of branches collected from this tree the day before the first spray application was made. The day following the spray application another large bouquet was collected from the same tree. The two bouquets were placed in water in jars in the insectary for 2 weeks to allow any curculio eggs in the young peaches to hatch. At the end of that time all the peaches on the two bouquets were dissected and the percentage wormy peaches determined. Table 1 sets forth the results.

Table 1.—Effect of parathion on curculio larvae in immature peaches.

Treatment	Total Peaches	Peaches with Larvae		Peaches with Live Larvae Per Cent
		Live	Dead	
Parathion (1 lb. 25%)	322	12	10	3.1
No spray	247	95	0	38.5

The data in table 1 show that the fruit was already infested to the extent of nearly 40 per cent by curculio when the first spray of parathion was applied. The parathion sprayed fruit was infested to the extent of 3 per cent 2 weeks after the spray was applied and the unsprayed check was 38.5 per cent infested. This represents a reduction of over 90 per cent as compared to the untreated fruit.

Experiment 2.—The manager of the Race peach orchards in Warren County in northern New Jersey decided to use parathion as an all purpose insecticide to control mites, plum curculio and oriental fruit moth in 1949. The first spray (1.5 pounds of 15 per cent parathion to 100 gallons of water) was timed to coincide with the date when three fourths of the husks were off the young peaches. This decision was based on the knowledge that parathion would kill those eggs or larvae of the plum curculio which were in the peaches at the time the spray was applied. Also it was anticipated the spray would be applied before any oriental fruit moth eggs hatched.

On the day the spray was applied the writer made a survey and found recently hatched oriental fruit moth larvae in the twigs. The size of the larvae indicated the majority of them were from 1 to 3 days old. The first spray was applied the same day the survey was made. Two days later all of the wilted peach twigs that could be found in one of the sprayed blocks were collected and carefully dissected and examined for live and dead larvae. Since the entire orchard was sprayed with parathion the only unsprayed check trees available were a few trees located around the house and barns and in nearby hedgerows. As many wilted twigs as could be found were collected from these unsprayed trees and dissected for live and dead oriental fruit moth larvae.

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology.

[2] Jour. Econ. Ent. 42(2): 330–5.

As soon as it was observed that parathion was killing fruit moth larvae in twigs in the northern New Jersey orchard a similar test was run in a peach orchard in Gloucester County in southern New Jersey. Twig growth and fruit moth development was approximately 10 days earlier in the Gloucester County orchard when the parathion spray (1 lb. of 25 per cent wettable powder to 100 gallons of water) was applied. Two days after the spray was applied wilted twigs from the parathion sprayed trees and wilted twigs from unsprayed trees were collected and dissected for live and dead larvae. The results obtained from the Warren and Gloucester County orchards are set forth in table 2.

Table 2.—Effect of parathion on oriental fruit moth larvae in peach twigs in two orchards in New Jersey.

TREATMENT	LARVAE IN TWIGS		
	Live	Dead	Missing
Parathion (1½ lbs. 15%)	3	24	21
Parathion (1 lb. 25%)	5	16	40
Unsprayed	10	0	7
Unsprayed	22	0	28

The data in table 2 show an appreciable kill of Oriental fruit moth larvae in peach twigs by parathion. In the Warren County orchard, where 1.5 pounds of 15 per cent parathion was used, the percentage dead larvae was greater than in the Gloucester County orchard where 1 pound of 25 per cent parathion was used. This is believed to be due to the fact that most of the larvae were recently hatched and had just entered the twigs in the Warren County orchard, whereas in the Gloucester County orchard many of the larvae were older and had burrowed deep in the twig or had transferred to other twigs.

EXPERIMENT 3.—The results obtained with parathion when sprayed on peach twigs in which the first brood of oriental fruit moth larvae were feeding were followed up by similar tests in three orchards against the second brood of larvae. Three orchards were selected; one in northern, one in central, and one in southern New Jersey. When an appreciable number of second brood larvae had entered the twigs a block of trees in each orchard was sprayed with parathion. Orchard number 1 in northern New Jersey was sprayed with 1.5 pounds of 15 per cent parathion wettable powder using a speed sprayer. Orchard No. 2 was sprayed with 1 pound of 25 per cent parathion using a single nozzle gun with the operator spraying from the moving spray rig. Orchard number 3 was sprayed with a single nozzle gun with the operator on the ground.

Two days after the sprays were applied, 100 recently wilted peach twigs were collected in each sprayed plot in each orchard. On the same day 100 recently wilted twigs were collected from unsprayed trees in each of the three orchards. The collected twigs were stripped of leaves and placed in battery jars with green apples where the larvae matured and spun cocoons in corrugated paper. They were then held in suitable containers until adult moths or parasites emerged. A second collection of 100 twigs was made in the sprayed and unsprayed sections of orchard No. 1 a week after the first collection was made. These were handled in the same manner as those collected 2 days after the sprays were applied. The results from this series of tests are set forth in table 3.

Table 3.—Effect of parathion on recently hatched second brood oriental fruit moth larvae feeding in peach twigs in 3 different orchards.

TREATMENT	LARVAE REARED FROM 100 TWIGS			PER CENT LARVAE PARASITIZED
	Orchard 1	Orchard 2	Orchard 3	
Parathion Sprayed	3	14	4	85.7
Unsprayed	33	52	29	71.9
Parathion Sprayed	1	—	—	—
Unsprayed	25	—	—	—

The data in table 3 support the data in table 2 and show that parathion sprayed on peach trees in which recently hatched larvae are feeding in the twigs will materially reduce the number of larvae reaching maturity. The data in table 3 also show that parathion does not selectively kill the parasitized larvae and leave the unparasitized larvae since 85.7 per cent of the larvae reared to maturity in the parathion sprayed area were parasitized compared to 71.9 per cent parasi-

tism of the larvae reared to maturity in the unsprayed area. All of the 14 specimens reared to maturity in the parathion sprayed area or orchard No. 2 were parasites.

EXPERIMENT 4.—The results obtained with parathion used against the larvae of plum curculio in peach fruit and oriental fruit moth larvae in peach twigs led the writer to investigate the effect of parathion on codling moth larvae after they gain entrance into the fruit. An opportunity to observe the effects of parathion on codling moth larvae after they enter the apple was afforded in two apple blocks on the Race farm in Warren County. On August 9 second brood codling moth larvae were found entering apples in a block of Red Delicious and McIntosh. The grower sprayed that day using 1.5 pounds of 15 per cent parathion wettable powder to 100 gallons of water. Two days later the writer examined approximately 75 stung apples. Approximately a third of these stings yielded dead larvae and in two-thirds the larvae were missing. No live larvae were found.

On August 26 a heavy infestation of second brood codling moth was discovered in another block on the same farm. A quick survey showed about half of the stings contained live larvae and the other half no larvae, alive or dead. It was also estimated that a third to half of the crop would be destroyed if the infestation was not controlled. The grower sprayed the block of trees the same day the infestation was discovered, using 1.5 pounds of 15 per cent wettable parathion powder to 100 gallons of water. Two days later 75 apples were collected which showed one or more stings per apple. A total of 107 stings on the 75 apples yielded 4 live larvae, 52 dead larvae and 51 stings with larvae missing. The four live larvae found were about one-third grown and had already reached the seed core before the spray was applied. One apple which showed six fresh stings on the day the block was sprayed was marked and 2 days later the stings were examined and a dead larva found in each of the stings.

The block sprayed with 1.5 pounds of 15 per cent parathion on August 26 contained McIntosh and the fruit was due to be harvested 2 weeks after the spray was applied. The amount of parathion residue at or near harvest was therefore an important consideration. Samples of fruit were collected from the tree and from dropped fruit under the tree on September 5. The samples were analyzed for parathion residue September 6 by the spray residue chemists of the New Jersey Agricultural Experiment Station. Fruit from the tree analyzed 0.106 parts per million of parathion and the fruit from the ground analyzed 0.054 parts per million.

SUMMARY.—Observations and experiments were carried on in 1949 in peach and apple orchards in New Jersey to determine the effect of parathion on recently hatched larvae of plum curculio, oriental fruit moth and codling moth after they gain entry into the host plant. Parathion-wettable powders were used under orchard conditions at 1 pound of the 25 per cent and 1.5 pounds of the 15 per cent to 100 gallons of water. By dissection and by rearing it was determined that a high percentage of the recently entered larvae of the three species were killed by the parathion. Whether the parathion killed by fumigation or by entering the galleries or by absorption through the plant tissues was not determined. Analysis of apples made 10 days after the spray was applied showed 0.1 part per million or less of parathion residue.

Control Tests on Sunflower Insects in Nebraska

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Many varieties and inbred lines of *Helianthus annuus L.* have been grown in observation plots at several locations in Nebraska since 1942. Yields in these plots have varied from complete failures to 1200 pounds of seed per acre. Failures or near failures were frequent and were due in most instances to insect damage. Sunflowers appear to be well adapted to Nebraska but, unless insects can be controlled economically, they are not a sound agricultural crop for this state. In 1948 research was begun to determine possible control measures for insects prevalent on sunflowers in Nebraska. This report discusses the 1948 and 1949 insect control studies.

PROCEDURES AND MATERIALS.—In 1948 and 1949 approximately 3 acres of the Advance hybrid variety were planted at Lincoln, Nebraska. These plantings were used as experimental areas for determining the effects of insecticidal sprays and dusts on insect populations. Individual plots, in 1948, consisted of six 42-inch rows, 200 feet in length. The treatments, which were applied July 10, consisted of benzene hexachloride dusts containing 1 and 5 per cent gamma isomer and DDT dusts containing 5 and 10 per cent DDT. These treatments and an untreated check plot were replicated four times.

In 1949 the experiment included 6 treatments and an untreated control, each replicated 4 times and two dates of planting, May 2 and June 8. Plots were 50 feet long and 8 rows in width. Wettable powder benzene hexachloride sprays were used for all treatments. Soil treatments were applied through a ten-foot weed boom operated two feet above the soil surface. A specially-designed, inverted, U-shaped boom was used in applying pre-bloom foliage sprays. Post-bloom foliage sprays were applied directly into the open heads through a four nozzle orchard boom. All sprays were applied with a Hardie estate sprayer operating at approximately 150 pounds pressure.

Before cleaning the seed to determine yields in 1948, samples of 100 seeds were taken from each of two replications to determine the amount of weevil infestation. Yields during both years were based on 40 feet of the two center rows of each plot. Plots in all cases were harvested within a week after complete maturity. Oil analyses of the seed were made by 5-hour extraction with diethyl ether in a Gold-fish extraction apparatus.

All statistical differences were calculated at the 5 per cent level of significance.

RESULTS AND DISCUSSIONS.—The effectiveness of two insecticides, DDT and benzene hexachloride, in controlling insects prevalent on sunflowers in 1948 and 1949 is shown in tables 1 and 2, respectively, Agronomic and chemical data obtained in these tests are shown in table 3. In the following paragraphs, each of the insects encountered in these tests is discussed from the standpoint of past control methods and results obtained in this study.

Seed Weevils. The sunflower seed weevils, *Desmoris constrictus* Say.[2] and *D. fulvus* Lec., have been recognized as a limiting factor in the commercial production of sunflowers. These insects are prevalent each year on wild as well as commercial sunflower varieties in Nebraska. Bigger (1930, 1931, 1942) recorded several chalcid and braconid parasites of *fulvus* but did not evaluate the control obtained. One of these parasites, *Microbracon mollitor* Say., was cited as a natural control by Satterthwait (1946), who stated that insecticidal control appeared impractical. In his tests, hand picking was compared with dust applications of calcium arsenate, lead arsenate, sodium fluoride, pyrethrum talc, hydrated lime and gypsum. Unfavorable results were obtained with all methods. Satterthwait suggested that fall plowing, crop rotation and the development of resistant hybrids might aid in the control of the weevils.

Tables 1 and 2 show that gamma isomer of benzene hexachloride applied

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[2] The assistance of various specialists in the Division of Insect Identification, U.S.D.A., Bureau of Entomology and Plant Quarantine, in the identification and confirmation of insect species involved in this study is appreciatively recognized.

Table 1.—The effects of dusting sunflower heads with DDT and benzene hexachloride July 10 on insects infesting sunflowers at Lincoln, Nebraska. 1948.

Date of Sampling	Mean Number of Insects					Least Significant Difference
	1 lb. DDT per acre	2 lb. DDT per acre	0.2 lb. BHC per acre	1 lb. BHC per acre	Untreated control	
	Seed weevils per head					
5- days after treatment	2.62	2.34	0.94	0.60	2.08	—
10- days after treatment	2.74	2.32	1.78	1.89	2.02	—
	Head moth larvae per head					
August 18	1.91	2.82	0.51	1.87	1.65	not sig.
	Arctiid larvae per leaf					
August 2	3.24	5.18	1.29	0.18	2.48	—
	Percentage stalks infested by borers					
August 20	57.5	65.0	52.5	27.5	55.0	24.0

at a rate of 1 pound per acre as a dust or a spray on sunflower heads significantly reduced the weevil population for 5 days. This decrease in the number of weevils per head did not, however, reduce the percentage of infested seed. Although results obtained indicate unsatisfactory weevil control, it is possible that properly timed applications of the insecticide would have been more efficient. Since treatments used in this study were applied after many of the flowers were in full bloom, applications early in the blooming period are suggested. DDT did not show promise in weevil control.

Head Moth. The sunflower head moth, *Homoeosoma electellum* (Hulst), has been reported as seriously injurious by many workers but little or no control work has been attempted. Satterthwait and Swain (1946) studied several parasitic flies and wasps but cited no chemical or cultural control methods.

Two different head moth control methods are indicated in the present data. Time of planting appears to be important. Sunflowers planted on May 2 had fully matured heads that had dried out by harvest time on September 21. This planting averaged less than one larva per head, even in untreated plots, at the time of harvest. Untreated plots planted on June 8 averaged nearly 3 larvae per head on September 21 and

Table 2.—The effects of benzene hexachloride sprays on insects infesting sunflowers at Lincoln, Nebraska. 1949.

Date of Sampling	Treatments[1]							Least Significant Difference
	Soil	Soil and Pre-bloom	Soil and Post-bloom	Pre-bloom and Post-bloom	Pre-bloom	Post-bloom	Untreated control	
	Seed weevils per head							
48 hrs. after post-bloom treatment, June 8 planting			0.12	0.18		0.25	0.52	0.16
	Head moth larvae per head							
August 3, May 2 planting	9.70	2.45	1.30	1.65	10.60	2.70	7.55	5.31
September 21, June 8, planting	1.55	0.32	1.72	0.72	0.75	1.12	2.70	1.044
	Percentage stalks infested by borers							
September 21, May 2 plantings	70.	100.	0	95.	95.	95.	100.	Not sig.
September 21, June 8 plantings	100.	100.	100.	100.	100.	100.	100.	—

[1] Soil treatments were applied at two pounds of gamma benzene hexachloride per acre on April 29 for the early planting and June 1 for the late planting, pre-bloom foliage treatments at 8 ounces of gamma on June 3 and July 9 respectively and post-bloom foliage treatments at 8 ounces of gamma July 28 and August 6.

Table 3.—The effects of applying insecticides and date of planting on yields and oil percentage of the Advance sunflower variety.

Treatment and Rate per Acre		Cleaned Seed: Yield per acre (pounds)	Cleaned Seed: Weight per bushel (pounds)	Cleaned Seed: Per Cent Oil	Uncleaned Seed: Per Cent Filled	Uncleaned Seed: Per Cent Unfilled
		1948 data				
DDT	1.0 lb.	197	16.7	13.1	21.5	65.0
DDT	2.0 lbs.	141	16.5	12.7	30.5	60.5
BHC	0.2 lb. gamma	546	20.0	18.4	21.0	64.5
BHC	1.0 lb. gamma	646	20.2	17.9	56.0	31.0
Control		303	18.2	15.7	23.0	63.0
Least significant difference		242				
	Benzene hexachloride treatments, 1949 data from May 2 planting[1]					
Soil (4/29) 2.0 lbs. gamma		941	28.8	32.2		
Foliage, pre-bloom (6/3) 0.5 lb. gamma		957	29.0	32.0		
Foliage, post-bloom (7/28) 0.5 lb. gamma		1048	28.9	33.3		
Control		1072	29.2	32.1		
	Benzene hexachloride treatments, 1949 data from June 8 planting[1]					
Soil (6/1) 2.0 lbs. gamma		393	26.5	29.2		
Foliage, pre-bloom (7/8) 0.5 lb. gamma		430	25.8	28.9		
Foliage, post-bloom (8/6) 0.5 lb. gamma		481	27.3	30.4		
Control		418	26.5	28.8		

[1] Differences between yields, test weights and oil percentages within dates is not significant, differences between dates is highly significant.

were still too succulent to harvest. The 1949 yield data shown in table 3 indicates that yields and oil percentages of the seed are also significantly higher on the early date of planting.

Benzene hexachloride also showed some promise of moth control. Differences in larval populations between treated and untreated plots, in 1948 were not significant. In 1949 however, when treatments were varied and timed, significant decreases in larval populations were obtained. Post-bloom foliage treatments gave the best larval control in the early planting. In the late planting all treatments seemed to have some effect. As in the case of the seed weevils, applications of benzene hexachloride early in blooming period are suggested. DDT did not seem to affect head moth populations.

Arctiids. Two well known arctiids, *Diacrisia virginica* (Cram.) and *Estigmene acrea* (Drury) developed injurious populations in the 1948 experimental plots. No insecticides were applied to control these insects but records were taken to determine effects of the original treatments. Benzene hexachloride gamma isomer produced a striking decrease in the larval population while DDT was followed by an equally striking increase. The natural inference from these data is that DDT eliminated the natural enemies of the arctiids without seriously affecting the hosts.

Severe to moderate leaf injury by these insects was sustained in all plots except those receiving 1 pound of the gamma isomer of benzene hexachloride. This injury is reflected in the 1948 yield data presented in table 3.

Stem borers. Several stem borers identified as *Hippopsis lemniscata* (F.), *Ataxia* sp. and *Mordellistena* sp. infested about 50 per cent of the flower stems in 1948 and nearly 100 per cent in 1949.

In 1948, a significant reduction in infested plants was obtained with a dust treatment of 1 pound of gamma benzene hexachloride per acre. Data collected in 1949, however, failed to show significant reductions of infested plants with any of the treatments used. The 1948 data given in table 1 indicate that biological studies and additional control tests should be conducted on these insects.

SUMMARY AND CONCLUSIONS.—Results of tests conducted at Lincoln, Nebraska, in 1948 and 1949 showed that benzene hexachloride was partially effective in the control of several species of sunflower insects. Control of *Diacrisia virginica*

(Cram.) and *Estigmene acrea* (Drury), was obtained with dust formulations of gamma benzene hexachloride. Dust and spray formulations of the same insecticide showed some promise of controlling *Desmoris constricta* (Say.), *Homoeosoma electellum* (Hulst) and several coleopterous stalk borers. These results indicate that commercial production of sunflowers in Nebraska with present varieties and insect control methods would be hazardous and impractical.

LITERATURE CITED

Bigger, J. H. 1930. A parasite of the sunflower weevil. JOUR. ECON. ENT. **23**(1): 287.
Bigger, J. H. 1931. Another parasite of the sunflower weevil, *Desmoris fulvus* (Lec.). JOUR. ECON. ENT. **24**(2): 558.
Bigger, J. H. 1932. An addition to the list of parasites of the sunflower weevil, *Desmoris fulvus* (Lec.). JOUR. ECON. ENT. **14**(3): 591.
Satterthwait, A. F. 1946. Sunflower seed weevils and their control. JOUR. ECON. ENT. **39**(6): 787–92.
Satterthwait, A. F., and R. B. Swain. 1946. The sunflower moth and some of its natural enemies. JOUR. ECON. ENT. **39**(5): 575–80.

Biology and Host Relationships of the Squash Vine Borer[1]

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The results of studies concerning the biology of the squash vine borer, *Melittia cucurbitae* (Harris), with particular reference to host plant resistance have been recently reported (Howe 1949). During the course of these field studies, insectary rearing techniques were developed which permitted closer observation of the biology and feeding habits of the insect. They were again utilized in 1949 to observe the feeding reactions on genera of cultivated cucurbits which have been introduced comparatively recently into the normal host range of the squash borer. This paper reports the techniques and results of the above.

INSECTARY REARING.—Field collected eggs provided the most satisfactory culture source. Eggs were more abundant and easily found on the stems of the preferred summer bush varieties of squash, *Cucurbita pepo*, or the Hubbard types, *C. maxima*, (Howe 1949). The eggs were removed with a sharp scalpel and placed in a petri dish containing moistened crumpled lens paper for observation of hatching and rearing. The following technique was employed: Holes 0.31 inch in diameter were bored in parallel rows in blocks of ordinary paraffin canning wax to a depth of 0.375 inch. The top surface of the cell block was carefully smoothed to permit close fitting of glass microscope slides which served as covers to prevent escape of larvae. A small cube of squash fruit rind was placed in each cell and the egg was placed in its natural position on the cube. This technique permitted rapid observation on the cube. This technique permitted rapid observation of large numbers of eggs. Upon hatching, larvae bored into the cube of rind, exuding a small amount of frass, leaving the egg in its original position. If frass was not yet visible hatched eggs were easily detected by the presence of a small jagged exit hole at the micropyle end. Considerable care was exerted in handling the eggs to avoid injury to the embryo. To determine the incubation period it was obviously necessary either to collect eggs immediately after oviposition in the field or from caged gravid females. The latter moths, when placed in a cage containing a squash plant, became excited and oviposited immediately without regard to location on the plant or demonstration of the care employed under normal conditions.

Four out of five field collected eggs hatched on the eighth day with the fifth hatching on the ninth. In the insectary, only 5 of 23 eggs hatched when placed on the surface of constantly moist soil in an open petri dish. In the field, 10 of 11 eggs in dry soil shaded by foliage hatched. No parasites emerged from eggs observed in the insectary or eggs closely

[1] New York Agricultural Experiment Station Journal Paper No. 824, April 7, 1950.

observed in the field. At times in some localities, eggs are subject to a high degree of parasitism by a tiny wasp of the family Scelionidae (Worthley 1923).

Larval development in the insectary was observed by removing the rind cubes containing young larvae and placing them in specially prepared segments of Summer Crookneck squash. The upper portion of each segment was cut off to permit the carving of a small niche to accommodate the rind cube containing the larva, after which the top portion was replaced. Daily observations were made by removing the top piece or, if necessary, cutting into the fruit where the larvae were boring. If the large segment of squash fruit was nearly consumed or seriously infected by rot the larvae were transferred to fresh segments similarly prepared. When larvae were full grown the entire fruit was transferred to battery jars containing an inch or two of damp sandy soil. Upon maturity, the larvae entered the soil and constructed the normal silken cocoons. Larvae feeding on fruit which was considerably rotted and soft left the fruit and migrated to the soil sooner than those given fresh fruits. As many as 15 larvae were reared together by using larger segments of squash. Summer squashes such as White Bush Scallop and Yellow Summer Crookneck were used as food because they were more abundant during the rearing period. Immature winter squash also served as a suitable food. Yellow Summer Crookneck was preferred because its shape was more convenient for use with rearing equipment. Rearing was most successfully carried out in a shady, well aerated place with temperatures not exceeding 80° F. At higher temperatures larvae attempted to migrate from the fruit and also the squash pieces were more subject to damage by rot organisms. Larvae appeared to relish a small amount of the reddish-brown rot which frequently developed in the fruit. Souring or fermentation of the fruit caused the larvae to become flaccid, followed by death unless removed to a fresh fruit. Data obtained by the above technique are summarized in table 1.

Modifications of this rearing method permitted the use of stems and leaf stalks as food. In one method, short stem sections were placed in the cells of the paraffin block instead of the fruit rind cubes.

Table 1.—Growth of fruit-reared squash borer larvae in an outdoor insectary at Geneva, N Y., July–August, 1948.

	No. Observed				
	4	8	11	12	35
	1st Instar	2nd Instar	3rd Instar	4th Instar[1]	Total
	Duration in Days				
Minimum	7	3	6	6	22
Maximum	7	12	9	11	39
Average	7.0	6.4	7.3	9.2	29.9

[1] Period of association with plant.

After the second instar was reached larvae were placed in larger stem sections or in fruit. Severed stem sections did not supply sufficient nutrients for growth of the larger larvae. Growing stems supplied abundant amounts of phloem exudate which apparently served as an important food source. In a second method, larvae were also introduced into growing plants by cutting a small oblique slit into the under side of the hollow leaf petiole. After larvae were inserted through the slit they migrated to the main stem and resumed their feeding activities. To prevent the leaf stalk from collapsing it was occasionally necessary to wrap it with tape. Leaf petioles with most of the foliage removed also served as a suitable food for early stages of larval growth. Petioles were made to stand upright in ordinary water glasses by packing cotton in the bottom of the glass around the centered leaf stalk base. Water was added to maintain stem turgor. Young larvae were either placed inside or outside the stem. In either case they made little effort to escape. Again after growth to second instar, larvae were carefully removed and transferred to a more abundant food supply for continued growth.

Occasional pupation was observed in the insectary during the summer, but no adult emergence occurred among the reared specimens until the next spring and summer. Cocoons were removed from the soil in the battery jars and placed about 2 inches below the soil surface in a wooden tray containing about 3 inches of soil which was moistened occasionally. The cocoons were exposed to normal outdoor temperatures in an unheated screened insectary. Adult emergence occurred in April from cocoons which had been placed in damp soil at room temperature for about 40 days. The remaining

adults emerged a few days before normal field emergence occurred.

PARTIAL SECOND GENERATION IN 1949.—Only a single generation of this insect has been believed to occur in New York. Observations of cast pupal skins in two fields approximately 40 miles apart in central New York indicated that a partial second generation occurred during 1949. The first cast skins were found near the base of attacked vines in a field a short distance north of Syracuse on September 9. Early in October, 26 cast skins were collected from a small experimental plot at Geneva. Later in October a search in the same plot resulted in finding only a single second instar larva, presumably of the second generation. Fall emergence of adults, initiating only a partial generation would, of course, reduce the potential number of adults emerging the next summer. A partial second generation of this insect is reported to occur normally in Virginia (Spencer & Henderson 1924).

CUCUMBERS, MELONS AND WATERMELONS AS HOSTS.—Britton (1909) and Sanderson & Peairs (1921) have indicated that cucumbers and melons are seldom attacked by the squash borer if squashes and pumpkins are available for oviposition. Whitcomb & Garland (1948) observed a complete lack of infestation in cucumbers, melons and watermelons in mixed plantings with squash and pumpkin and pointed out the present conflicting statements regarding injury to all commonly cultivated cucurbits. Confusion in the current literature has undoubtedly resulted from frequent early reports (Kent 1888, 1890, 1891) (Kellicott, 1892) (Sirrine 1894) of severe damage to all cultivated cucurbits. In some cases, these authors received grower reports, probably erroneous, of serious injury to cucumbers and melons. Harris (1828) in his original description of *Melittia cucurbitae* stated that the specific name would indicate the genus of its food plant. In order to determine the true status of other genera as hosts, studies of the feeding reactions of the borer on them appear to be necessary.

Cucumber, *Cucumis sativus*, melon, *C. melo*, and watermelon, *Citrullus vulgaris*, are of African and Asiatic origin and were first reported in America late in the fifteenth century (Tapley *et al.*, 1937), thus their present status as suitable hosts, if true, should represent a comparatively recent adaptation of the native squash borer to new exotic forms of definitely different botanical nature. The restriction of genus *Melittia* to the Cucurbitaceae for food and the further specialization of species to certain cucurbits (Englehardt 1946) is indicative of the specialized food habits of the group as a whole. The commonly preferred hosts, squashes and pumpkins, are of Tropical American origin and forms of *Cucurbita pepo* spread early into Mexico and southern United States (Tapley *et al.*, 1937), thus serving as hosts for the northward migration of the squash borer from its probable point of origin, which according to Englehardt (1946) was also Tropical America.

Using techniques just described, attempts were made to rear squash borer larvae on the stems and fruits of cultivated cucurbits of exotic origin. The results are tabulated below:

Even though most larvae bored into and fed on the cucurbit tissues, none were capable of continued development in either the stems or fruits. When plant tissues began to rot or were badly riddled fresh food was supplied, and was usually partially consumed. Larval development was greatly retarded even though considerable frass was produced and larvae remained imbedded in the tissues for periods as long as 8 days before death. They

Table 2.—Feeding and survival of first instar squash borer larvae after introduction into cucurbits other than squash and pumpkin. Geneva, N. Y., 1949.

	CUCUMBER *Cucumis sativus*		MUSKMELON *Cucumis melo*		WATERMELON *Cucumis vulgaris*	
NUMBER	Stem	Fruit	Stem	Fruit	Stem	Fruit
Introduced	6	13	10	17	23	15
Boring into tissues	5	10	8	12	22	51
Moulted	1	2	0	0	1	1
Surviving	0	0	0	0	0	0

were also sluggish, stunted and lacked the creamy-white coloration of normal larvae. This probably indicated improper nutrition. Death nearly always occurred during the first instar. Painter (1936) has indicated that such is usually the case in plants which are resistant to insect attack. Although the plants are not immune to to attack, this apparent unsuitability as food indicates that only minor injury by the larvae could be normally expected. Though strains of *Melittia cucurbitae* may exist which are capable of inflicting more serious injury, there is probably little likelihood that larval development could be completed. The stems of these plants, with their tough, woody character, resemble those of the highly resistant *Cucurbita moschata* (Carruth & Howe 1948, Howe 1949).

SUMMARY.—The squash borer, *Melittia cucurbitae*, may be easily reared to the adult from field collected eggs. Either the fruit or stems of preferred hosts serve as food. The fruit of Early Summer Yellow Crookneck was more convenient and supplied sufficient nutrients for complete larval development. Utilizing the described larval rearing techniques, attempts were made to rear squash borer larvae on watermellon, *Citrullus vulgaris*, Cucumber, *Cucumis sativus*, and cantaloupe, *Cucumis melo*. These plants are frequently listed as important hosts to the squash borer especially in older publications. The tough woody nature of their stems, similar to those of the highly resistant *Cucurbita moschata*, raises doubt as to their suitability as hosts for squash borer larvae. Since the plants are of African or Asiatic origin, their present existence as hosts would constitute a comparatively recent adaptation of the native squash borer to a distinctly different plant species of remote origin. None of the 84 newly hatched larvae introduced into the stems of fruits of these cultivated cucurbits was able to utilize the tissues for for continued development. Although most larvae entered the tissues, development was retarded, color was abnormal and death usually resulted before the second instar was reached. A partial second generation of the squash borer was observed in 1949 in northern New York.

LITERATURE CITED

Britton, W. E., 1909. Insects attacking cucurbitaceous plants in Conn. 8th Annual Rept. of the State Entomologist. 806–7.

Carruth, L. A. and W. L. Howe, 1948. Factors affecting the use and phytotoxicity of DDT and other insecticides for squash borer control. JOUR. ECON. ENT. **41**(3): 352–5.

Englehardt, George F. 1946. The North American clear-winged moths of the family Aegeriidae. U. S. Nat. Mus. Bull. **190**: 181–91.

Harris, T. W. 1828. Insects. New England Farmer. **7**: 33–4.

Howe, W. L. 1949. Factors affecting the resistance of certain cucurbits to the squash borer. JOUR. ECON. ENT. **42**(2): 321–6.

Kellicott, D. S. 1892. Notes on the Aegeriidae of Central Ohio. Canadian Entomologist. **24**: p. 43.

Kent, G. H. 1888. Some notes from Mississippi. Insect life **1**: 17.

Kent. G. H. 1890. Notes of the season from Mississippi. Insect Life **2**: 283.

Kent, G. H. 1891. Notes from Mississippi. Insect Life **3**: 337.

Sanderson, E. D. and L. M. Peairs, 1921. Insect pests of farm garden and orchard. John Wiley & Sons. p. 353.

Painter, R. H. 1936. The food of insects and its relation to resistance of plants to insect attack. Amer. Nat. **70**: 547–66.

Sirrine, F. A. 1894. Some insects injurious to squash, melon and cucumber vines. N. Y. Agr. Expt. Sta. Bul. **75** n.s. p. 415.

Spencer, Herbert and H. S. Henderson, 1924. The control of squash insects. Va. Agr. Expt. Sta. Bul. **49**: 401–11.

Tapley, W. T., W. D. Enzie, and G. P. Van Eseltine, 1937. The vegetables of New York, Vol. 1: The cucurbits **4**: 1–131 Rpt. N. Y. Agr. Expt. Sta. 1935.

Whitcomb, W. D. and W. J. Garland, 1948. Susceptibility of cucurbitaceae to squash borer. Proc. Amer. Soc. Hort. Sci. **51**: 445–7.

Worthley, H. N. 1923. The control of the squash vine borer in Mass. Mass. Agri. Expt. Sta. Bul. **218**: 70–80.

Relation of *Empoasca fabae* to Hopperburn and Yields of Potatoes[1,2]

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Although the potato leafhopper, *Empoasca fabae* (Harris), has long been known to cause hopperburn and severe reductions in yields of potatotes, more quantitative information is desirable concerning the degree of hopperburn and the extent of yield reductions which result from different leafhopper populations.

The amount of leafhopper foliage injury has been observed to be directly proportional to the number of leafhoppers present (Ball 1918; Poos & Johnson 1936; Poos 1938; Sleesman & Wilson 1943). Wolfenbarger (1936) reported that as potato leafhopper injury increased the yields decreased in a linear relationship. Sleesman & Wilson found close negative correlations between nymph populations and yields and between percentages of dead foliage and yields. MacLeod (1939) and Skaptason & Blodgett (1941) observed that relatively low populations of *Empoasca fabae* apparently had a considerable effect on yields. Although large yield increases had been recorded frequently as a result of leafhopper control prior to the advent of DDT, the more effective control achieved with DDT (Granovsky 1944a, b) brought a greater realization of the extent of yield reductions attributable to the potato leafhopper (Sleesman, *et al.* 1945; Wilson & Sleesman, 1945; Sleesman & Wilson, 1946; Wolfenbarger & Heuberger, 1946). The frequent observation that potato plants sprayed with DDT were more vigorous with larger, flatter leaflets (Heuberger & Wolfenbarger, 1944; Sleesman *et al.* 1945) is a good illustration of the previously unrecognized injury by *Empoasca fabae* as pointed out by Heuberger & Stearns (1946) who found that plants sprayed with DDT were identical in appearance to unsprayed plants in the absence of potato leafhoppers. In an interesting study on potato yields under different leafhopper densities, Wolfenbarger & Heuberger (1946) observed that yields were sharply increased as counts of leafhoppers approached zero.

There is little evidence to indicate whether potato leafhopper injury influences the subsequent vigor and yielding ability of tubers from infested plants. Dudley (1920) reported that when Triumph potatoes were planted from tubers of plants killed by hopperburn the previous year, the resulting plants all succumbed to hopperburn early in the season in spite of periodic applications of bordeaux mixture. Since Dudley was comparing Triumphs with other varieties in this experiment it is possible that his results might be explained by the varietal susceptibility of Triumphs to leafhopper injury. Carter (1939) referred to Dudley's work and suggested that one effect of leafhopper injury might be to reduce the vigor of vegetative reproductions from the affected parent plant. It was of interest to investigate this possibility which is of considerable importance to the grower of certified seed.

METHODS AND PROCEDURE.—Triumph potatoes were planted in 24 outdoor field cages, two plants per cage, at Brooklyn Center, Minnesota, in 1948 and 1949 and exposed to different densities of potato leafhoppers. In 1948 the potatoes were planted on May 11. On July 8, 25, 50, 100, 200, and 300 *Empoasca fabae* nymphs were introduced into five of six cages arranged at random. Four replications were used. At the time the leafhoppers were introduced the plants were partially wilted due to a severe drought, and many of the young leafhoppers did not survive. Plants in two end cages were killed by the drought and dropped from the experiment. However, subsequent showers improved the condition of the remaining plants, and the leafhoppers became quite abundant in some cages. A full generation was completed by mid-August. Some plants had up to 40 per cent hopperburn by August 17, and the more heavily infested plants were dead by August 30. Yields from leafhopper infested plants and non-infested plants from the same

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[2] Part of this material was included in a thesis presented by the senior author to the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the Ph.D. degree.

original tuber units were sacked separately and planted at Grand Rapids, Minnesota, in 1949 to determine whether vigor and yielding ability of the tubers was influenced by potato leafhopper density on the parent plant.

In 1949 Triumph potatoes were planted in outdoor cages on May 10. On July 9 from 0 to 300 *Empoasua fabae* adults were introduced in each cage as in the previous year. Although weather conditions were responsible for an unusual amount of physiological tipburn during the latter half of July, the season was somewhat more favorable for potatoes in 1949 than in 1948. Nymphs were abundant and hopperburn fairly extensive in some cages by July 30. During August the increased prevalence of tipburn and early blight made estimations of hopperburn very difficult. Some vines were dead by August 18.

Periodical observations were made on caged plants both years. Adult leafhoppers were counted, or estimated if numerous, and nymphs were counted per 10 leaves in each cage. Percentages of hopperburn were estimated by comparison with a diagrammatic chart. Other types of foliage injury such as stunting and reduced size of leaflets were evident; however, the amount of hopperburn was considered a reliable evaluation of injury for observations within a single variety. The relation of leafhopper density to hopperburn and yields was determined from data taken at the time of maximum leafhopper populations and before foliage injury resulted in death of the vines. The yield of each hill was recorded at the end of the season.

NYMPH POPULATIONS AND HOPPERBURN.—The number of nymphs per 10 leaves counted on August 17, 1948, was closely correlated with per cent hopperburn ($r = 0.911$ for 20 degrees of freedom). Nymphs per 10 leaves on July 31, 1949, were also closely correlated with per cent hopperburn ($r = 0.909$, 20 d. f.). The similarity of results is shown by the regressions of hopperburn on *Empoasca fabae* nymphs (Fig. 1). These results are in agreement with those of Sleesman & Wilson (1943) who reported a close correlation between leafhopper nymph populations and percentages of dead foliage on the Cobbler variety.

NYMPH POPULATIONS AND YIELDS.—In the 1948 experiment, yields were negatively correlated with numbers of nymphs per 10 leaves on August 17 ($r = -0.464$). Data plotted on graph paper seemed to show trends toward a logarithmic curve. The regression of yields on nymphs per 10 leaves was found to have a barely significant departure from linearity. Correlation of yields with log nymphs per 10 leaves was -0.602.

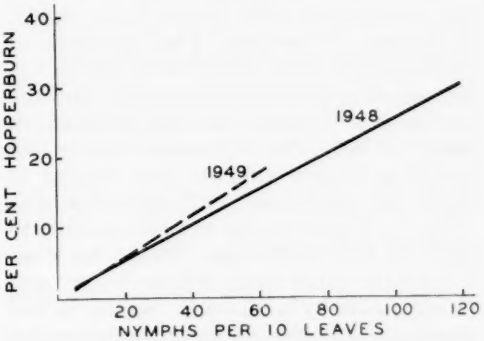

FIG. 1.—Regressions of per cent hopperburn on *Empoasca fabae* nymphs per 10 leaves. Brooklyn Center, Minnesota. August 17, 1948, and July 31, 1949. Correlations were 0.911 in 1948 and 0.909 in 1949 (20 degrees of freedom).

In the 1949 experiment, the correlation of yields with nymphs per 10 leaves on July 31 was -0.415. Here also the regression showed a significant departure from linearity, and the correlation of yields with log nymphs was -0.600. Although the yields differed considerably in the two years, presumably due to more favorable growing conditions during 1949, the similarity of the correlations and regression curves is quite striking. (Fig. 2).

It is evident from the regression curves that relatively great yield reductions result from low leafhopper densities. Since the caged plants were subjected to attack by *Empoasca fabae* for a shorter period of time than normally occurs under field conditions, it is expected that yield reductions due to leafhopper injury might be even greater under field conditions than indicated in these experiments. Similar curves were presented by Wolfenbarger & Heuberger (1946). These authors reported regressions of yields on leafhopper densities ranging from log -0.100 to -0.3048. Corresponding figures for the present experiments were log -0.111 for 1948 and log -0.118 for 1949.

EFFECT OF HOPPERBURN ON YIELDS — Per cent hopperburn estimated on August 17, 1948, was negatively correlated with yields ($r = -0.474$, 20 degrees of freedom). The relationship appeared to be best expressed by a logarithmic curve. However, the departure from linearity did not quite reach the 5 per cent level of significance. The correlation of yields and log hopperburn was -0.595.

Hopperburn in 1949 had a relatively low correlation with yields ($r = -0.365$, 20 degrees of freedom). The regression of yields on per cent hopperburn had a significant departure from linearity, and the correlation of yields and log hopperburn was -0.543. The regression curves for yields on hopperburn are very similar to those for yields on leafhopper nymphs (Fig. 3). These results are comparable to those of Bald & Helson (1944) who studied potato tuber moth foliage injury and found yields to be directly related to leaf areas when plotted on logarithmic graphs.

EFFECT ON SUBSEQUENT YIELDS.— Triumph tubers from plants which had low *Empoasca fabae* populations in 1948 produced somewhat higher yields in 1949 than tubers from plants which had high populations (Table 1); however, this difference was not significant. The correlation of 1949 yields with 1948 *E. fabae* nymph populations was -0.211 (22 d. f.) which was not significant. The correlation of -0.358 for 1949 yields and per cent hopperburn in 1948 was likewise not significant.

Table 1.—1949 yields from tubers of plots exposed to low and high densities of *Empoasca fabae* in 1948.

TREATMENT	TOTAL YIELDS 1949
Triumph cage experiment	
Low *E. fabae* density 1948	350.7 lbs. (120 hills)
High *E. fabae* density 1948	319.0
Cobbler field plots	
Low *E. fabae* density 1948	162.3 lbs. (90 hills)
High *E. fabae* density 1948	143.7
Sequoia field plots	
Low *E. fabae* density 1948	252.6 lbs. (90 hills)
High *E. fabae* density 1948	268.3

(Differences not significant)

Cobblers from plots dusted periodically with DDT in 1948 produced somewhat higher yields in 1949 than tubers from the same original tuber units obtained from plots in which leafhoppers had remained uncontrolled the previous year (Table 1). In the same experiment Sequoias exposed to a high leafhopper density in 1948 yielded more in 1949 than those from plots dusted in 1948 with DDT. The apparent tendency for a graeter 1949 yield response to 1948 leafhopper control in the susceptible Triumph and Cobbler varieties as compared with the more resistant Sequoia is interesting, but none of these differences reached the level of significance and little confidence can be placed in the results.

If feeding injury by *Empoasca fabae* does influence the subsequent vigor and yielding ability of potato tubers from infested plants, the present experiments were not sufficiently precise to demonstrate it. We must, therefore, conclude

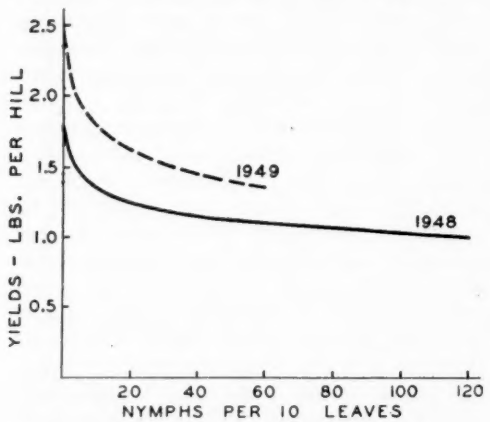

FIG. 2.—Regressions of yields on *Empoasca fabae* nymphs per 10 leaves. Brooklyn Center, Minnesota. Nymph counts were made on August 17, 1948, and July 31, 1949. Yields were recorded at end of the season. Correlations were -0.602 in 1948 and -0.600 in 1949 (20 degrees of freedom).

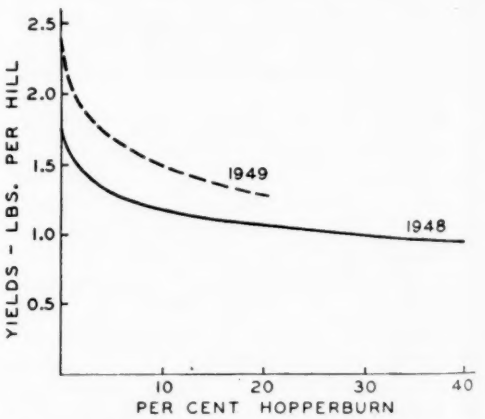

FIG. 3.—Regressions of yields on per cent hopperburn. Brooklyn Center, Minnesota. Hopperburn was estimated on August 17, 1948, and July 31, 1949. Yields were recorded at end of the season. Correlations were -0.595 in 1948 and -0.543 in 1949 (20 degrees of freedom).

that *E. fabae* appears to have little, if any, adverse effect on the yielding ability of tubers to be used for seed.

SUMMARY.—Observations on injury to potatoes caused by different populations of *Empoasca fabae* indicate a close straight-line relationship between nymph populations and per cent hopperburn. The relations of yields to nymph density and per cent hopperburn were best expressed by logarithmic curves. Relatively great yield reductions resulted from low leafhopper densities, and with further increases in leafhopper populations the yield reductions became proportionally less great. *E. fabae* injury appeared to have little, if any, adverse effect on the subsequent yielding ability of tubers from affected plants.

LITERATURE CITED

Bald, J. G., and G. A. H. Helson, 1944. Estimation of damage due to potato moth, *Gnorimoschema operculella* (Zell.) Jour. Council Sci. and Ind. Res. **17**: 30–48.

Ball, E. D. 1918. Leaf burn of the potato and its relation to the potato leafhopper. Science **48**: 194.

Carter, Walter. 1939. Injuries to plants caused by insect toxins. Bot. Rev. **5**: 273–306.

Dudley, J. E. 1920. Control of the potato leafhopper (*Empoasca mali* LeB.) and prevention of "hopperburn." JOUR. ECON. ENT. **13**: 408–15.

Granovsky, A. A., 1944a. Tests of DDT for the control of potato insects. JOUN. ECON. ENT. **37**: 493–9.

Granovsky, A. A. 1944b. The value of DDT for the control of potato insects. Amer. Potato Jour. **21**: 89–91.

Heuberger, J. W. and L. A. Stearns, 1946. Compatibility of DDT and fungicides on potatoes. JOUR. ECON. ENT. **39**: 267–8.

Heuberger, J. W., and D. O. Wolfenbarger, 1944. Preliminary report on DDT in the potato fungicide program. Phytopath. **34**: 1003.

MacLeod, G. F. 1939. Some quantitative aspects of insect injuries to potato plants. Amer. Potato Jour. **16**: 179–84.

Poos, F. W. 1938. Insects in relation to diseases of cereal and forage crops. JOUR. ECON. ENT. **31**: 24–38.

Poos, F. W., and H. W. Johnson, 1936. Injury to alfalfa and red clover by the potato leafhopper. JOUR. ECON. ENT. **29**: 325–31.

Skaptason, J. B., and Blodgett, F. M. 1941. Factorial studies on potato dusting materials. Amer. Potato Jour. **18**: 1–9.

Sleesman, J. P., H. L. Gui, and J. D. Wilson, 1945. DDT and other new materials for spraying potatoes. Proc. Ohio Veg. and Potato Grow. Assoc. **30**: 140–7.

Sleesman, J P., and Wilson, J. D. 1943. Comparison of fixed coppers and bordeaux mixture in the control of insects and diseases on mulch-grown Irish Cobbler potatoes. Ohio Agr. Expt. Sta. Bimonthly Bul. **28**(223): 173–83.

Sleesman, J. P., and J. D. Wilson, 1946. The effect of DDT on potato insect populations. Proc. Ohio Veg. and Potato Grow. Assoc. **31**: 182–92.

Wilson, J. D., and J. P. Sleesman, 1945. Possible influences of new organic pesticides on experimental test procedure. Ohio Agr. Exp. Sta. Bimonthly Bul. **30**(232): 27–30.

Wolfenbarger, D. O. 1936. Insect and disease evaluations in potato experiments. JOUN. ECON ENT. **29**: 187–9.

Wolfenbarger, D. O., and J. W. Heuberger, 1946. Potato yields from different potato leafhopper densities. Amer. Potato Jour. **23**: 389–95.

MORE RETIREMENTS

Dr. T. B. Symons, Dean of the College of Agriculture and Director of the Extension Service, and one time entomologist at the University of Maryland will retire late in the summer of 1950. Dr. Symons has been connected with the University of Maryland since his graduation there in 1898, after which for a period of 10 years he was active in the campaign against the San Jose scale and other insects. At a testimonial dinner honoring Dr. Symons on July 17, 1950, it was announced that the new agricultural building had been named "Symons Hall."

Joseph S. Wade, Entomologist in the United States Department of Agriculture, retired on July 31, at age 70, after over 37 years of government service, all of it in the Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine. Of this period, 4 years were spent in field and laboratory research in the Middle West, and 33 years in administrative and research work in Washington. Mr. Wade will continue to reside in Washington, D. C., at Argonne Apts., 1629 Columbia Road, N. W., Zone 9.

Artificial Defoliation of Cotton and Boll Weevil Control[1]

E. W. Dunnam and S. L. Calhoun,[2,3] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

From 1942 to 1946 experiments on artificial defoliation of cotton with dusting-grade calcium cyanamide were conducted on field plots at Stoneville, Miss., in connection with a mechanical harvesting program. Studies were made of the stage of plant development at which complete defoliation was most likely to occur, on the time of day and the rate at which the chemical should be applied, on the influence of defoliation on boll opening, on the efficiency of machine picking, and on the grade of lint.

Gull (1943) and Gull & Adams (1945) have reported on some of this work. Gull reported the same grade of lint cotton from machine-picked undefoliated and defoliated plants, but less picker and cord waste in spinning tests of samples from defoliated plants. Gull & Adams, in comparing machine-picked cotton obtained under each condition, reported that defoliation was beneficial in that machines picked a greater percentage of open cotton from plants, that the moisture content of seed cotton was lower, that less foreign matter was gathered, and that on an average the lint samples were improved.

From the inception of these studies, observations and records have been made to determine the influence of defoliation on the control of the boll weevil, *Anthonomus grandis* Boh. Gull & Dunnam (1947) and Dunnam *et al.* (1948) reported that early defoliation checked weevil development by destroying squares and blooms, and that regardless of the date of defoliation, no weevils were found to complete development in second-growth squares before the cotton was killed by frost. They found that defoliation caused weevils to migrate from treated fields and under average weevil infestations reduced the damage to bolls developing late in the season near the top of plants. Where weevil infestation was held to a low level throughout the season and cotton was defoliated within a short time after the last application of poison, weevils did little damage to young bolls.

During 1949 the authors conducted additional tests at Stoneville on the defoliation of cotton heavily infested with boll weevils. No other cotton pests were considered to be of much economic importance. The first objective of these investigations was to study more closely the reaction of the boll weevil to the progressive abscission of squares, young bolls, and leaves after treating the cotton plant with a defoliant. The second objective was to investigate further the value of defoliation on impeding or preventing weevil multiplication.

Methods.—In the first phase of the investigation dusting-grade calcium cyanamide was applied to cotton plants on which the weevils were feeding. The chemical was dusted with an airplane at the rate of 20 pounds per acre to one 35-foot swath on each of two 10-acre fields of cotton on the morning of September 19 in the presence of a light dew. The untreated portion of each field was used as a check. From the time the chemical was applied until the plants were completely defoliated, daily records were made on the percentage of abscission of squares, blooms, young bolls, and leaves, and on the number of weevils found by examining 200 squares and young bolls in each field. Boll weevil and abscission records were obtained on the same days.

In the second phase, calcium cyanamide was applied in each of four experiments at the rate of 20 to 22 pounds per acre. There were four replicates in each experiment. In the first experiment the chemical was applied on August 23, 30, and September 7 to Delfos 651 cotton in plots 8 rows wide and 0.20 acre in area with a 4-row dusting machine mounted on a tractor. In the second experiment the chemical was applied to Deltapine 15 cotton in plots 8 rows wide and 0.42 acre in area; in the third, to Bobshaw 1 and Deltapine 15 cottons in plots 60 to 90

[1] The investigations were made in cooperation with the Delta Branch of the Mississippi Agricultural Experiment Station, and the Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture. Certain phases of this study were carried on under the Research and Marketing Act of 1946.

[2] W. R. Smith, W. L. Lowry, and M. V. Courtney assisted with these investigations.

[3] Presented at the meeting of the American Association of Economic Entomologists at Tampa, Fla., December 13–16, 1949.

rows wide and 10 acres in area; and in the fourth, to Deltapine 15 cotton in plots 32 rows wide, 100 feet long, and 0.25 acre in area. In these three experiments the chemical was applied by airplane on September 9, 19, and 20, respectively. After the first killing frost on November first three-hundred consecutive cotton stalks near the center of each plot were inspected to determine the number of plants with second-growth leaves, squares, blooms, and young bolls. All fruiting forms large enough to supply food for a weevil grub were dissected and examined to ascertain the stage of weevil development.

RESULTS.—In the first phase defoliations began on the day after the calcium cyanamide was applied (Table 1). The squares were the first forms to shed. The plants did not react to the defoliant in the same degree in each field, an indication that soil type or levels of moisture and fertility may influence the rate of shed. The almost immediate response of the plant to the defoliant is an important factor, because squares are the preferred food of the boll weevil and by depriving them of this food the schedule of development is interrupted even before defoliation is complete.

Shedding of small bolls and leaves began on the second day in each treated field, but the general pattern was the same as that observed in shedding of squares. By the third day small bolls had dropped in great numbers in both fields. At this time 99 per cent of the squares, 60 per cent of the young bolls under 15 days of age, and 5 per cent of the leaves had dropped in field 1. In field 2 only 70 per cent of the squares, 40 per cent of the young bolls, and 3 per cent of the leaves had abscissed.

At the same time the weevil population had greatly decreased in both treated fields, but had greatly increased in the untreated portions of each field. This increase suggested that the weevils had migrated out of the treated to the untreated portions. It was apparent that, as protective leaf cover and food became scarce, the weevil had transferred to cotton having normal foliage, squares, and young bolls in search of food and protection from the sun. The same general trend of weevil exodus was correlated with abscission of squares and young bolls in each field until the end of 8 days, when all such forms had dropped. When observations were discontinued, 80 per cent of the leaves had shed in the first field and 75 per cent in the second. At this stage of defoliation few weevils remained in the treated portion of the fields.

In the second objective of the investigation, in which cotton of the same age and variety was treated with calcium cyanamide on three dates, defoliation was obtained within 8 to 10 days after treatment. The leaf drop from cotton treated on August 23, 30, and September 7 was 90, 75, and 65 per cent, respectively. Although seasonal conditions of 1949 were

Table 1.—Plant response and boll weevil population after application of calcium cyanamide on September 19, 1949.

Date of Observation	Per Cent of Abscission on Treated Plants			Number of Weevils per 100 Squares and Bolls on	
	Squares	Blooms and Young Bolls	Leaves	Treated Plants	Untreated Plants
		Field 1			
Sept. 20	15	0	0	50	42
21	80	10	2	58	46
22	99	60	5	9	75
23	100	80	30	10	86
27	100	100	80	7	129
		Firld 2			
Sept. 20	5	0	0	75	37
21	50	5	2	75	57
22	70	40	3	49	66
23	98	60	20	27	99
27	100	100	75	5	127

very favorable for the production of second growth on cotton plants, it is significant in Experiment 1 (Table 2) that there was practically no difference in the amount of second growth, including the development of squares on cotton treated on August 23 and September 7, respectively. The youngest bolls that did not abscise after treatment on August 23 were approximately 18 days old at the time the defoliant was applied.

Table 2.—Percentage of cotton plants developing second growth by November 1, after being treated with calcium cyanamide on different dates in August and September 1949.

Date of Treatment	No Terminal Second Growth	Terminal Second Growth But No Squares	Terminal Second Growth and Squares
	Experiment 1		
Aug. 23	31	57	12
30	23	55	22
Sept. 7	26	62	12
	Experiments 2, 3, and 4		
Sept. 9	77	23	0
19	74	26	0
20	50	50	0

During normal seasons, experiments have shown that about 20 days after the "cut-out" (excessive shedding of blooms and young bolls) plants defoliated more completely and developed less second growth than when treated at any other time. The same general pattern was obtained during this season but was not expected because of an unusually heavy rainfall. Cotton in plots treated on August 30, approximately 25 days after cut-out, produced the highest percentage of plants with second growth and squares. In previous experiments it was found that the yield was not reduced when the leaves were removed 20 days after cut-out. Moreover, no weevils developed beyond the second instar in squares on plots treated as early as August 23. This early treatment materially reduced the number of weevils available to go into hibernation by providing a food-free period of several weeks in which no squares, blooms, or young bolls were available for weevil feeding or development.

In experiments 2, 3, and 4 (Table 2) cotton was treated on September 9, 19, and 20, respectively, about 20 days after cut-out. In each experiment a high percentage of plants produced no second growth, and where second growth did occur it was very light. The new leaves rarely developed to a diameter of more than 1.5 inches. No squares, blooms, or young bolls that would afford food for weevils developed on any of the plants.

In all experiments defoliating the cotton checked plant growth, accelerated opening of bolls, and permitted an earlier harvest. In experiment 1 cotton stalks could be cut earlier and the land fallowed early in the fall. In the three later experiments defoliation was a satisfactory substitute for cotton-stalk destruction, since no significant second growth developed.

SUMMARY.—Studies were made at Stoneville, Miss., to determine the response of the adult boll weevil, *Anthonomus grandis* Boh., to the defoliating action of calcium cyanamide on cotton plant, and the value of this practice as a weevil control measure. It was found that defoliation of cotton caused an almost immediate exodus of weevils to untreated fields. When cotton was treated as early as August 23, the boll weevil did not reach maturity in any second growth forms before frost on November 1. Removal of leaves, squares, and young bolls artificially checked plant growth, accelerated opening of bolls and made an earlier harvest possible. Under these conditions cotton stalks can be destroyed earlier in the season, thereby offering a supplement to the regular cotton-stalk destruction campaign as a boll weevil control measure, or a substitute for destroying stalks.

Defoliation is practiced extensively in the Mississippi Delta as an aid to mechanical harvesting, but it is doubtless very beneficial for boll weevil control.

LITERATURE CITED

Dunnam, E. W., S. L. Calhoun, and P. W. Gull. 1948. Chemical defoliation of cotton. Miss. Farm Res. 11(3): 3–6.

Gull. P. W. 1943. Cotton defoliation. Delta Branch, Miss. Agr. Expt. Sta. Service Sheet 364.

Gull, P. W., and J. E. Adams. 1945. Mechanical production of cotton. Miss. Agr. Expt. Sta. Bul. 423.

Gull, P. W., and D. W. Dunnam. 1947. Experiments in chemical cotton defoliation. Agr. Chem. 2(6): 33–5.

DDT for Control of the Pink Bollworm in Mexico in 1946

A. J. Chapman, L. C. Fife, G. L. Smith, and J. C. Clark, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Investigations of DDT for control of the pink bollworm, *Pectinophora gossypiella* (Saund.), were conducted at Torreon, Coahuila, Mexico, during the summer of 1946. Large-scale tests were designed to determine the economic value of this insecticide and small-plot tests to secure information on the most effective dosages and intervals of application of dust and spray formulations.

Large-Scale Tests.—The large-scale tests were conducted in 20 fields of cotton. A total of 278 acres were dusted and 237 acres in adjacent areas were left untreated as checks. Each field was divided into nearly equal parts, half being dusted with 10 per cent of DDT in pyrophyllite and the other half serving as a check. The fields were selected for uniformity of stand, plant growth, soil, and insect population. They ranged from about 6 to 40 acres, averaging 25.7. The dust applications in four fields were made wth single-nozzle rotary hand guns, in one field with a 6-row oscillating-nozzle tractor duster, and in 15 fields with a Stearman PT-17 airplane. The airplane duster carried a maximum load of 600 pounds of dust, an amount sufficient to treat about 40 acres. The swaths were spaced 40 to 60 feet apart.

The number of applications in the various fields ranged from 5 to 9, averaging 6.4. Very few rains occurred through out the season, and only once was a dust application in a single field washed off within 24 hours.

The DDT-pyrophyllite mixture was applied at weekly intervals early in the morning, when the air was usually calm, at an average rate of 16.3 pounds per acre-application. Generally there was no dew.

Occasionally dust drifted into the check areas, but it is believed that the amount was not sufficient to influence materially the infestation or the yield.

Dusting was started usually about the time the cotton commenced opening when the green-boll infestation in most fields had reached 20 per cent; however, the infestation varied in this respect considerably, ranging from about 2 to 49 per cent.

Infestation counts were made at 14-day intervals throughout the season. Two hundred bolls were collected at random in each of the treated and check areas, and these bolls were examined to determine the number of larvae per boll and the percentage of bolls infested.

The control ranged from 33 to 81 per cent, averaging 58 per cent. These figures are based on the seasonal average of 1.64 and 3.95 larvae per boll in the treated and check areas, respectively. The control increased in all fields until four or five applications had been made, and then decreased, probably because of increased moth migration from untreated fields and scarcity of green bolls.

The infestation rapidly increased in the dusted plots in all fields after August 15; this was true with respect to the percentage of bolls infested, as well as to the number of larvae per boll. However, the build-up was not so rapid in the dusted plots as in the check plots. The final green-boll infestation in the treated areas averaged 81 per cent and in the check areas 96 per cent. The seasonal average infestations were 52 and 71 per cent, respectively.

Although considerable reduction in the infestation was obtained from DDT dusting, the pink bollworm damage was not entirely eliminated.

There was an average gain of 259 pounds of seed cotton per acre (14 per cent) as a result of dusting, this gain being significant at the 5-per cent level when the data were analyzed statistically. This gain was due principally to pink bollworm control. The net profit was about 8 dollars per acre.

An analysis of seed-cotton samples from the dusted and check plots showed no significant difference in the grade or staple, or in the oil or protein content of the seed. Most of the lint was classified as Strict Low Middling Spotted and hid an average staple length of 0.9 inch. These

[1] In cooperation with the Department of Agriculture of Mexico. L. F. Curl, T. R. Stephens, and Dennis H. Currie assisted in making arrangements to conduct DDT investigations in Mexico, and in furnishing equipment, storage and office facilities, and large quantities of DDT dust mixtures.

results indicate that most of the badly damaged cotton was left in the field because it was difficult to pick.

In only two of the experimental fields were aphids sufficiently abundant to cause economic damage. However, both fields had been dusted twice with calcium arsenate for bollworm control. In the other fields no cotton insects except pink bollworms were abundant enough to cause appreciable damage.

SMALL-PLOT TESTS.—The small plots were arranged in five series of randomized blocks with three to six treatments per block. In series 3 and 5 the blocks were 0.5 acre with three replicates per treatment, and in series 1, 2, and 4 they were 0.2 acre with four replicates per treatment. The treatments consisted of DDT dusts and sprays at various concentrations and dosages.

The dust was applied with single-nozzle rotary hand guns and the spray with single-nozzle hand sprayers. The insecticides were applied early in the morning, when the air was usually calm; rarely was there any dew.

For the spray 0.4 pound of technical DDT was dissolved in 0.75 pint of xylene; and the solution was further diluted with water to the desired strength, 7 ml. of an aralkyl polyether alcohol,[1] per gallon of finished spray being used as the emulsifier.

Fifty-bolls from each plot were examined at 14-day intervals, and the percentage of bolls infested and the number of larvae per boll were recorded.

In series 1, 2, and 3. (Table 1), when DDT dust was applied at the rate of 1 to 3 pounds of technical DDT per acre-application, or approximately 6 to 24 pounds per acre for the season, the control increased with the dosage used, regardless of the concentration.

Further to clarify the relationship between dosage and control, the small plots were grouped as follows according to the amount of technical DDT applied for the season: 5 to 10 pounds, 10.1 to 15 pounds, and 15.1 to 20 pounds. At average seasonal dosages of approximately 7, 12, and 17 pounds of technical DDT per acre in the respective groups, the control averaged about 52, 62, and 73 per cent. Therefore, a 10-per cent increase in control was obtained for every additional 5 pounds of technical DDT applied.

Table 1.—Effects of various concentrations of DDT dust in pyrophyllite applied at different rates per acre at weekly intervals for pink bollworm control.

DDT Concentration, Per Cent	Pounds of DDT per Acre Application	Average Seasonal Infestation		Per Cent Control
		Per Cent of Bolls Infested	Larvae per 100 Bolls	
Series 1 (6 applications, average of 4 plots)				
5	0.93	61	179	60
10	0.98	72	337	24
	1.82	58	179	60
20	2.52	48	108	76
	3.12	41	74	83
Check (untreated)	—	80	447	—
Minimum significant difference (5% level)	—	7	63	—
Series 2 (8 applications, average of 4 plots)				
5	0.85	47	135	42
10	0.86	47	134	42
	1.66	39	103	55
20	2.28	38	92	60
	3.08	38	84	64
Check (untreated)	—	60	234	—
Minimum significant difference (5% level)	—	6	34	—
Series 3 (5 applications, average of 3 plots)				
10	1.68	32	66	67
20	3.44	25	51	74
Check (untreated)	—	63	200	—
Minimum significant difference (5% level)	—	8	106	—

These results were almost exactly the same as those obtained in the large-scale tests, *i.e.*, 58 per cent control with 10.3 pounds of technical DDT applied per acre for the season.

In series 4 and 5, sprays and dusts containing DDT were compared at various dosages. In series 4, there were 3 14-day treatments and 2 weekly treatments, each 14-day dosage being about twice the weekly dosage. In series 5, sprays were compared with dusts at weekly intervals of application.

Applications of DDT dust and spray at 14-day intervals gave about the same control as weekly applications (Table 2). The 14-day applications of spray gave significantly better control than 14-day applications of dust; however, there was no significant difference between the spray and dust when applied at weekly intervals. The spray gave better adherence, but the dust gave better coverage of the plants.

In addition to the small-plot tests described, above, DDT dust was compared with DDT spray in two fields of about 9 acres each. In one field the DDT was applied with a power tractor, and in the other with hand machines. In both fields

[1] *Triton X-100.*

Table 2.—Comparison of DDT spray and dust applied at weekly and 2-week intervals for pink bollworm control.

TREATMENT	INTERVAL OF APPLICATION (WEEKS)	POUNDS OF DDT PER ACRE-APPLICATION	AVERAGE SEASONAL INFESTATION		PER CENT CONTROL
			Per Cent of Bolls Infested	Larvae per 100 Bolls	
Series 4 (6 and 3 applications, average of 4 plots)					
Dust 20%	2	3.10	46	112	54
10%	1	1.83	40	76	69
Spray	2	3.50	36	58	76
	1	1.82	29	47	81
Check (untreated)		—	66	247	—
Minimum significant difference (5% level)			10	50	—
Series 5 (8 applications, average of 3 plots)					
Dust 10%	2	1.69	33	49	77
Spray	1	1.84	15	24	91
Check (untreated)		—	70	263	—
Minimum significant difference (5% level)			7	39	—

the insecticides were applied at weekly intervals. The spray was a xylene emulsion containing 0.4 pound of DDT per gallon, and was applied at the rate of about 4.5 gallons per acre-application. The dust contained 10 per cent of DDT in pyrophyllite and was applied at approximately 15 pounds per acre. Two hundred bolls were examined per treatment at 14-day intervals throughout the season to determine the degree of infestation.

In these tests DDT spray gave about the same control as DDT dust (Table 3). The two fields averaged approximately 75 per cent control with about 10.5 pounds of technical DDT applied per acre during the season.

The various DDT formulations tested in all the small-plot experiments produced no significant gains in yield of seed cotton.

SUMMARY.—Investigations on the control of the pink bollworm, *Pectinophora gossypiella* (Saund.), with DDT were conducted in the Laguna District of Mexico during the summer of 1946.

In large-scale tests an average of 6.4 applications of 10 per cent DDT dust made at weekly intervals at the average rate of 16.3 pounds per acre gave 58 per cent reduction in the pink bollworm population on 278 acres of cotton. The infestation in the dusted cotton increased rapidly after August 15, but the build-up was not so rapid as in the untreated plots. Dusted fields produced on an average 259 pounds more of seed cotton per acre than nondusted fields. The net profit was about 8 dollars per acre.

Table 3.—Comparison of DDT spray and dust at weekly intervals with hand and power machines for pink bollworm control.

TREATMENT	ACREAGE	NUMBER OF APPLICATIONS	POUNDS OF DDT PER ACRE-APPLICATION	AVERAGE SEASONAL INFESTATION		PER CENT CONTROL
				Per Cent of Bolls Infested	Larvae per 100 Bolls	
Hand-machine application						
Spray	4.2	6	1.8	43	106	74
Dust	4.2	6	1.5	51	136	67
Check (untreated)	4.2	—	—	77	415	—
Power-machine application						
Spray	5.0	7	1.8	52	119	79
Dust	5.0	7	1.5	52	110	81
Check (untreated)	4.8	—	—	92	575	—

There was no difference in the grade and staple or in the oil or protein content of the seed in samples collected from the dusted and nondusted plots.

DDT dust applied at the rate of 1 to 3 pounds of technical DDT per acre-application, or about 6 to 24 pounds per acre for the season, increased the control with the quantity used, regardless of the concentration of the mixture.

When the results for the dusted plots were grouped according to the amount of technical DDT applied per acre for the season, the control averaged 52, 62, and 73 per cent for total dosages of about 7, 12, and 17 pounds of DDT. Thus approximately a 10 per cent increase in control resulted for every additional 5 pounds of technical DDT applied.

Weekly applications of dust and spray gave about the same control; 14-day applications of either gave the same control as weekly applications; however, 14-day applications of spray were significantly better than 14-day applications of dust.

Biology and Control of *Asterolecanium* Scales on Oaks in California

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A number of scale insects belonging to the genus *Asterolecanium* are pests of oak trees. Many oaks in the San Francisco Bay region and scattered localities in northern California have suffered severe injury during recent years as a result of asterolecanium infestations, and the terminal growth, branches, or smaller trees are often killed. No studies have previously been made of the biology of these scales in California, and very little information has been available regarding their control.

The classification of the genus *Asterolecanium* was in a state of confusion prior to the excellent revision by Miss Russell (1941). Members of this genus which occur on oaks in the United States were all previously considered under the name *A. variolosum* (Ratzeburg).

Asterolecanium variolosum, as redefined by Miss Russell, is a European species which has been carried to Australia, India, Chile, and North America. It is widespread in the eastern United States and Canada and was recorded from Stockton, California, in 1913 (Essig, 1913). The writers have encountered a single infestation of this species in Marin County, California.

Asterolecanium minus Lindinger is the most common pit scale on oaks in California. This species was orginally described from Europe, and it has been established in Pennsylvania for many years. Essig (1944) first recorded it from California.

Asterolecanium quercicola (Bouché) is often abundant on California oaks. This species was originally known from Europe and has since been recognized in South Africa, New Zealand, and North America. In the United States it is known to be established in several eastern states, and it was originally recorded from California on the basis of a single collection made on the Stanford University campus in 1931 (Russell 1941).

The species of *Asterolecanium* which inhabit California oaks show a decided preference for the white oak group. *A. variolosum* has been noted only on the English oak, *Quercus robur* L., in this state. *A. minus* and *A. quericola* may be found in large numbers on the native valley oak, *Q. lobata* Née, and blue oak, *Q. douglasii* H. & A. Occasionally, severe infestations may be found on the coast live oak, *Q. agrifolia* Née, and the California black oak, *Q. kelloggi* Newb., but many of these trees escape serious damage.

REPRODUCTION.—*Asterolecanium minus* and *A. quercicola* are both ovoviviparous and parthenogenic. No males have been found in California. This agrees very closely with the observations made by Parr (1940) in regard to the reproduction of *A. variolosum* in Connecticut. Similarly there is but a single generation annually.

It was originally believed by the authors that a summer control program for asterolecania would have to be correlated with crawler emergence, and efforts were made to determine the time of crawler appear-

ance and the seasonal reproductive pattern in California. Bands of .75 inch width masking tape were placed on infested twigs of a number of trees, and the bands were ringed with *Tanglefoot*. The bands were replaced weekly, and crawlers were counted in the laboratory.

In the San Francisco Bay area, near Woodside, during 1949, the first crawler emergence of *Asterolecanium minus* on valley oak and blue oak was approximately May 1. This was followed by very rapid reproduction near the middle of May and a strong decrease in the number of crawlers early in June. During the latter part of June, during July, and during the first part of August, there was sustained reproduction although considerably lower than the peak rate in May. During the latter part of August and during September, reproduction declined steadily. The last crawlers were found near the middle of September.

In the San Francisco Bay area, at Berkeley, during 1949, the rate of reproduction of *Asterolecanium quercicola* on English oak presented a similar picture. Emergence was somewhat later, however, the spring peak occurring about the end of May. The summer emergence remained proportionately low.

There was no correlation of changes in rate of reproduction with concurrent temperature means, maxima, nor minima. The highest temperatures (weekly average above 69° F. and maximum above 90° F. at Woodside; weekly average above 65° F. and maximum above 81° F. at Berkeley) occurred in June following the peak of spring emergence and again in September after emergence was nearly over. The lag of about two weeks in reproduction at Berkeley was possibly due to generally lower temperatures in this vicinity.

CONTROL.—There is a very high mortality among the young pit scales, some of which is possibly due to certain predaceous mites (cheyletids and laelaptids) and thrips (certain phlaeothripids) that are found commonly on twigs of California oaks. However, no parasites nor diseases of oak asterolecania have been found in California.

The use of oil as a dormant spray has been recommended for many years for control of asterolecanium scales on deciduous oaks (Hauser 1918; McDaniel 1930; Felt & Rankin 1932; Flint & Farrar, 1940; Essig 1944). No control methods have been available for infestations on live oaks.

Because there has been general dissatisfaction among arborists and other workers in California with the results of dormant oil sprays, it seemed advisable to obtain numerical data on the effect of such a spray on *Asterolecanium minus*.

The dormant oil tests were made at Lafayette, California, each treatment being made on three valley oaks about 20 feet high, while two similar trees were maintained as a check. The tests all employed 5 per cent emulsion-type dormant oil. One treatment was with the dormant oil alone; one was with the addition of 2 pounds of 50 per cent wettable DDT powder per 100 gallons of diluted emulsion; and one was with the addition of 1 quart of 60 per cent toxaphene emulsion (containing 1.5 pounds actual toxaphene per quart) per 100 gallons of diluted emulsion.

The treatments were made under cool, cloudy conditions on February 21, 1949. Spraying was done with a conventional rig employing an orchard gun having a number 6 disc, and with 400 pounds of pressure at the pump. About 25 gallons were used for each treatment.

An index of the degree of scale infestation was obtained from five terminal branches which were cut at random from each group of trees. Five subsamples were obtained from each branch, the subsamples consisting of twigs which were cut at random. The number of live scales was recorded for each twig, and the corresponding length and diameter of the twigs (varying from 20 to 60 mm. in length and from 2 to 10 mm. in diameter) were noted. The infestations were then calculated on a basis of scales per square centimeter of twig surface. In the case of new growth during the following season, the infestations were counted on a basis of the proximal 2.5 cm. of green twig.

Counts which were made 3 months after the dormant treatments indicated that a very high kill of the overwintering females had been obtained, although this had not been apparent at the end of two months. Seven months after treatment (Table 1) counts were made of the young scales. The control appeared excellent on older wood, but a considerable number

Table 1.—Summary of results of dormant oil sprays on February 22, 1949, for control of *Asterolecanium minus*.

Treatment	Pretreatment (Feb. 21)	Post-Treatment (Aug. 24)	
	Scales/cm.²	Scales/cm.² (old wood)	Scales/2.5 cm. (new growth)
5% oil emulsion	1.2	0.0+	3.6
5% oil emulsion+2 lbs. DDT (50% wettable)	0.3	0.0+	3.2
5% oil emulsion+1 qt. toxaphene (60% emulsion)	1.5	0.0+	3.7
Check	0.8	0.7	1.9

Table 2.—Summary of results of light-medium oil combination sprays on May 21, 1949, for control of *Asterolecanium minus*.

Blue Oaks	Pretreatment (May 20)	Post-Treatmeht (Sept. 14)	
	Scales/cm.²	Scales/cm.² (old wood)	Scales/cm.² (new growth)
2% oil emulsion+1 qt. toxaphene (60% emulsion)	4.7	0.0+	0.1
Check	3.5	4.1	15.0
Valley Oaks			
2% oil emulsion (containing 4.5% DDT)	3.8	4.8	9.1
Check	3.5	2.9	7.4

Table 3.—Summary of results of light-medium oil combination sprays on May 21, 1949, for control of *Asterolecanium minus*.

Blue Oaks	Scales/cm.² Pretreatment	No. of Bands	Average Crawlers per Band per Week May 26 to July 28		
			May 26	Average	July 28
2% oil emulsion 1 qt. toxaphene (60% emulsion)	4.7	4	12	4.6	5
Check	3.5	2	408	208	160
Valley Oaks					
2% oil emulsion (containing 4.5% DDT)	3.8	7	296	122	74
Check	3.5	6	465	149	89

of scales was found on the new growth which had appeared after spraying. It thus appeared that the dormant application had persisted as a repellent to the crawlers, and the new generation from surviving females was concentrated where the greatest damage to the tree could be incurred.

There was no apparent difference in the treatment with dormant oil alone in comparison with the addition of either DDT or toxaphene to the oil.

Further experimental work[1] was conducted near Woodside, California. Both valley oaks and blue oaks which were heavily infested with *Asterolecanium minus* were sprayed on May 21, 1949, following the peak of spring reproduction of asterolecania in this area. Two oak trees, about 15 to 20 feet high, were included in each treatment, while four similar trees were maintained as checks. One treatment consisted of 2-per cent emulsion type light-medium foliage oil containing 4.5 per cent DDT, while the other treatment consisted of 2-per cent emulsion-type light-medium foliage oil along with 1 quart of 60-per cent toxaphene emulsion (containing 1.5 pounds actual material per quart) per 100 gallons of diluted emulsion.

Spray applications were made with a conventional rig employing an orchard gun having a No. 7 disc and with 350 pounds pressure at the pump. About 10 gallons of spray material were used per tree.

An analysis of the sampling data which were obtained from the dormant oil experiment had indicated that a more satisfactory index of scale infestation could be obtained from the use of 10 samples consisting of 3 subsamples each. Accordingly, three twigs were cut from each of 10 branch terminals from each tree, and the infestations were determined on a basis of scales per square centimeter of twig surface. Pretreatment counts were based on overwintering females only, while the post-treatment counts were based only on the new generation of scales.

A comparison of pretreatment counts with counts made nearly four months after treatment (Table 2) shows that excellent control was obtained with oil and toxaphene, while oil and DDT gave negligible control.

Band counts of crawlers were also made on the trees which had been sprayed. These counts (Table 3) indicate that there was practically no reproduction following oil and toxaphene treatment, while the oil and DDT did not appear to affect crawler activity for more than about one week.

[1] Acknowledgment is made of the aid rendered by the San Mateo County Agricultural Commissioner's Office.

Two valley oaks having very heavy infestations of *Asterolecanium minus* were sprayed on July 27, 1949. Although the treatments were not replicated, the observations of these tests appeared to be significant. There was no apparent control with toxaphene alone at a rate of 1 quart of the 60 per cent emulsion per 100 gallons of water. One hundred per cent control was obtained with 2 per cent emulsive-type light-medium foliage oil[2] together with 1 quart of the 60 per cent toxaphene[2] emulsion per 100 gallons of diluted emulsion.

In the case of all trees sprayed with foliage oil and toxaphene combinations, incidental observations indicated that excellent control was obtained of oak aphids, *Myzocallis* spp., spider mites, *Paratetranychus* n. sp., and California oakworms, *Phryganidia californica* Pack., which were abundant on the checks.

Limited tests which were conducted on small trees during June indicated that parathion at a rate of 1.5 pounds of 25 per cent wettable powder per 100 gallons of water gave 100 per cent control, although there was considerable survival from a dosage of 1 pound of the same material per 100 gallons of water.

SUMMARY.—1. *Asterolecanium minus* is the most abundant pit scale on oaks in northern California, although *A. quercicola* is found commonly. *A. variolosum* is seldom encountered. These scales cause serious damage to oaks, especially the valley oak and blue oak among native trees.

2. *A. minus* and *A. quercicola* crawlers are produced from early May to late September in the San Francisco Bay area. The greatest peak of crawler production occurs within two or three weeks after first emergence.

3. A 5 per cent emulsion-type dormant oil, with or without the addition of DDT or toxaphene, was found to give a very high kill of *A. minus*. However, numerous progeny were found on the new growth during the following summer, and a repellent action of the dormant oil on older wood was indicated.

4. A 2 per cent light-medium foliage oil together with 1.5 pounds actual toxaphene (formulated as an emulsion) gave excellent control of *A. minus*. Results of applications made during the spring or summer indicated that all stages of the scales were killed. Toxaphene alone or a 2 per cent light-medium foliage oil containing 4.5 per cent DDT both gave unsatisfactory control.

5. The light-medium foliage oil and toxaphene combination also gave excellent control of common oak aphids, spider mites, and caterpillars.

[2] Furnished by courtesy of the Shell Chemical Co.

LITERATURE CITED

Essig, E. O. 1913. Insect notes. Monthly Bul. Calif. State Commis. Hort., **2**(10): 705.

Essig, E. O. and W. M. Hoskins. 1944. Insects and other pests attacking agricultural crops. Calif. Agr. Ext. Circ. **87** (rev.).

Felt, Ephraim Porter and W. Howard Rankin. 1932. Insects and diseases of ornamental trees and shrubs. McMullan Co., New York.

Flint, W. P. and M. D. Farrar. 1940. Protecting shade trees from insect damage. Ill. Agr. Expt. Sta. Circ. **509**: 1–59.

Houser, J. S. 1918. Destructive insects affecting Ohio shade and forest trees. Ohio Agr. Expt. Sta. Bul. **332**: 161–487.

McDaniel, E. I. 1930. Soft scales injurious to deciduous ornamentals. Mich. State College Agr. Circ. Bul. **133**: 1–17.

Parr, Thaddeus. 1940. *Asterolecanium variolosum* Ratzeburg, a gall-forming coccid, and its effect upon the host trees. Yale Univ. School Forestry Bul. **47**: 1–49.

Russell, Louise M. 1941. A classification of the scale insect genus *Asterolecanium*. U.S.D.A. Misc. Publ. **424**.

Effect of Technical Benzene Hexachloride and Lindane on the Flavor of Tomatoes and Potatoes[1]

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Benzene hexachloride has been found to be highly effective in the control of a wide range of insect species. Since the material has been available to workers about 125 papers reporting benzene hexachloride investigations have appeared in the Journal of Economic Entomology. A large part of these investigations have been concerned, directly or indirectly, with the odor and the disagreeable musty flavor which the chemical may impart to the treated product. A number of these reports are contradictory, particularly in reference to flavor contamination.

Several factors may be responsible for the apparent inconsistencies that occur in the literature. Different conditions may effect different results from year to year. The possible influence of soil pH apparently has been given but little study. Reports prior to the advent of lindane lacked the analysis of the "pure" gamma isomer materials, or often the gamma isomer content was below 95 per cent. Rohwer (1949) states, "It is urged that all experimenting with benzene hexachloride report the results in a way that will clearly describe the composition of the material tested." Furthermore, individual tastes vary widely and more use of authoritative taste panels is indicated, as is analysis for residues. Recently, some reports in the literature have dealt with benzene hexachloride residues. Hoskins (1949) reports residues of 0.1 ppm. of benzene hexachloride in tomatoes, 0.3 ppm. in potatoes which were grown in soil treated with this material.

Research has indicated that the gamma isomer is largely responsible for the insecticidal qualities of benzene hexachloride, whereas its flavor-contaminating characteristics are caused largely by the other isomers. In an effort to investigate the possibility of eliminating objectionable qualities, a series of new formulations of technical benzene hexachloride and of lindane were made available for testing.[5] The investigations included a study of the effect of soil pH on benzene hexachloride contaminations when these materials were applied to both alkaline and acid soils and to plants growing in these soils. The treated products were canned and submitted to a panel of judges for taste tests and to chemists for benzene hexachloride residue analyses. The tests were conducted in the greenhouse; since there was no wash-off when the plants were watered, the accumulation of residues was enhanced.

Experimental Methods.—Tomatoes and potatoes were grown in the greenhouse in 12-inch clay pots water-proofed on the inside with an asbestos-asphalt compound. The benzene hexachloride preparations were added to the soils at the rate of 2 pounds of the gamma isomer per acre, calculated on the basis of dry soil per acre.[6] Spray treatments involving the same test materials were applied to the plants as supplementary treatments at the rate of 3 ounces of the gamma isomer to 100 gallons of water. In the potatoes, the primary source of flavor contamination was probably the soil treatment, but this might have been enhanced by the sprays. In the tomatoes, the spray treatments were the apparent means of influencing the flavor contamination of the fruit; however, the soil treatments would make the effect more severe should the tomato be able to absorb, translocate, and deposit the contaminating entities of benzene hexachloride in the fruit.

Tomato Investigations.—The soil (Wooster silt loam) chosen to grow the Globe (Strain A) tomatoes had a pH of 6.6 and a specific conductivity of 57

[1] This investigation was supported by a grant of funds issued to the Ohio Agricultural Experiment Station by the Columbia Chemical Division of the Pittsburgh Plate Glass Company.

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[5] Materials furnished by the Pittsburgh Plate Glass Company. Analysis of the gamma isomer of lindane by the method of Kimball and Tufts of the Hooker Electrochemical Co. showed a gamma content above 99 per cent. The authors are indebted to Mr. Kenneth Dress and associates, of the Columbia Chemical Division, Pittsburgh Plate Glass Company, Department of Horticulture, for this analysis.

[6] It was assumed that an acre of dry soil 6 inches deep weighs 1000 tons, a value commonly accepted by agronomists.

reciprocal ohms (times 10^{-5}). Enough manure and balanced commercial fertilizers were added to raise the salt concentration to about 125 reciprocal ohms. One-half of this soil received hydrated lime at the rate of 14 tons per acre, and the remaining half received superfine dusting sulfur at the rate of 0.96 tons per acre.

The benzene hexachloride materials used were all prepared to 6 per cent gamma isomer content (Table 1). Each treatment, as well as the untreated check, was replicated 6 times in each of the two soil types. The materials were mixed thoroughly with sterilized soil and the treated pots were set on glazed saucers in order to prevent the loss of materials through leaching. The spray treatments, which augmented the soil treatments, were applied at 10-day intervals. A total of five sprays were applied; the last application was made 15 days before the first picking.

The second picking was made 16 days later, and the fruit was taken into the Fruit Processing Laboratory of The Ohio State University for canning after each picking. Two weeks after the processing date the fruit was submitted to a panel of judges from that laboratory for flavor testing.

POTATO INVESTIGATIONS.—Irish Cobbler potatoes were grown in two kinds of muck soil. Since it was deemed inadvisable to add lime to muck soil, an alkaline (calcareous) muck soil was obtained which had a pH of 7.5. The other muck soil had a typical acid reaction of 5.6.

The muck soil was prepared in about the same fashion as the upland soil, except that it was not sterilized. Besides the five materials tested on the tomatoes, an additional distilled technical benzene hexachloride was used. Each treatment, as well as the check, was again replicated 6 times on each of the two soil types. The spray treatments were applied at 10-day intervals; the last treatment was made 42 days before harvest. The potatoes were then canned and tasted by the panel one week after canning.

JUDGING AND ANALYSES.—The taste panel was composed of various staff members and graduate students of the Departments of Horticulture and Home Economics of the Ohio State University. Eight to 10 experienced judges met at each session, although the same individuals were not all present at every session. The taste reactions of the judges to benzene hexachloride were standardized with results comparable to Davis (1948), *i.e.*, a majority of the judges were able to taste

Table 1.—The effect of benzene hexachloride treatments on the flavor of canned tomatoes: mean scores of six taste panel sessions held on three different days.

Tomatoes Tasted	Treatment[1]														Min. Sig. Dif.[2]
	A	G	B	H	C	I	D	J	E	K	F	L	F*	L*	
First Picking	3.2	3.8	3.3	3.5	3.7	3.1	4.9	3.6	5.6	5.6	6.1	7.5			1.8 2.5
Second Picking	3.7	3.2	3.9	2.7	3.1	2.8	5.7	5.5	4.8	5.2	8.3	7.0		8.7	1.9 1.7
Second Picking	4.6	2.4	3.3	2.5	3.4	3.2	6.4	5.7	6.6	5.8	7.8	8.2	9.3	9.1	1.9 1.8
Mean	3.8	3.1	3.6	2.9	3.4	3.0	5.7	4.9	5.7	5.5	7.4	7.6			
Over-all Treatment Mean[3]	3.5±.3		3.2±.2		3.2±.2		5.3±.3		5.6±.3		7.5±.3				0.9

[1] The treatments were as follows:
A,G —Technical benzene hexachloride
B,H —Technical benzene hexachloride stabilized
C,I —Technical benzene hexachloride stabilized and washed
D,J —Pure gamma benzene hexachloride (lindane)
E,K —Pure gamma benzene hexachloride stabilized and washed (lindane)
F,L —Check, untreated
F*,L*—Check, untreated; sample made known to judges
A–F —Alkaline soil
G–L —Acid soil

[2] Minimum significant difference at the 1 per cent level.

[3] Standard Error included.

the 6 per cent gamma materials in water at a dilution of 1:1,000,000 and all were able to taste them at a dilution of 1:100,000.

Tasting sessions were held in mid-morning and mid-afternoon. Six or eight samples were usually tasted by each judge in each session and a 2-minute interval was allowed between samples. The tomato samples were tasted as a puree, and the potatoes were tasted in diced form. The panel judges were instructed to score their taste reactions numerically from 1 to 10 as follows: 1–5, mustiness detected in the sample; 6–10, slight off-flavor to perfect. In some of the tasting sessions, two untreated check samples were submitted to the judges; the identity of one was made known (known check) and the other was coded as were the treated samples (unknown check). The unknown check was included in all sessions.

The influence of soil pH on samples treated with a given preparation was determined by comparing the two respective samples—alkaline and acid soil-grown—against each other. The samples were set before the panel members in pairs, and the judges were instructed to rate them, using the same procedure that was used in evaluating the treatments.

Individual scores were tabulated and these data were subjected to analysis of variance tests to determine the significance of variations in scores due to treatment, judge, soil, and in some cases, to the interactions of these three primary sources each with the other.

The method of Davidow & Woodard of the Food and Drug Administration was used for the benzene hexachloride residue analyses.[1] This involved extraction of benzene hexachloride, dehydrochlorination to a mixture of trichlorobenzenes, and measurement of the 1, 2, 4-trichlorobenzene content by ultraviolet absorption. To improve sensitivity, 500-gram samples of tomatoes and potatoes were extracted instead of the suggested 100 grams; this process was carried out in a Waring Blendor as described by Tressler (1947), using methylene dichloride as the solvent. Representative samples from the technical benzene hexachloride treatments and the pure gamma benzene hexachloride treatments were analyzed.

RESULTS.—*Soil reaction.*—In the tomato investigations, the limed soil increased in pH from 6.6 to 7.3 in 7 weeks after transplanting and attained maximum alkalinity—7.6—at first harvest, about 8 weeks later; the sulfured soil decreased in pH from 6.6 to 6.0 and attained 5.3 in the same periods, respectively.

In the potato investigations, the pH of the two types of muck remained at 5.6 and 7.5 throughout the experimental period.

Tomato investigations.—The canned tomatoes were scored on three dates at six separate tasting sessions. The results from each session were analyzed statistically to determine the variance ascribable to judge and treatment. The treatment means from each session are given in table 1. At the end of the six sessions the data were subjected to combined analysis of variance, and the major source of variation in the scores was found to be treatment; neither soil type nor any of the interactions produced a significant variance.

Untreated samples were judged significantly different from the lindane-treated samples in only two of the six sessions. In every case the unknown check samples scored lower than 10—the highest possible score. The means ranged from 6.1 to 8.3. The mean score of the known checks, on the other hand, ranged from 8.7 to 9.3. It must be pointed out that the known check samples always scored higher than the unknown checks, a fact difficult to explain. (It appears that a psychological factor complicates the evaluation of results.)

The data were divided sharply into two categories: in one group, the samples all had received lindane preparations; in the other group, the samples all had received technical benzene hexachloride preparations. Generally, any one, or all members of one group were significantly different from any or all members of the other group, but there were no significant differences between members of the same group.

Since scores below five were to be identified as musty, it is evident that samples treated with technical benzene hexachlo-

[1] For the residue analyses, the authors are indebted to Dr. William E. Bissinger and Mr. Robert Fredenburg of the Columbia Chemical Division, Pittsburgh Plate Glass Company.

Table 2.—Residues of tomatoes and potatoes treated with 6 per cent gamma isomer formulations of technical benzene hexachloride and lindane as related to flavor contamination.

Material Used (Soil and Spray Treatments)	Tomatoes		Potatoes	
	Residue (ppm)	Mean Taste Rating	Residue (ppm)	Mean Taste Rating
Technical	0.6	3.5±.3	0.7	6.3±.5
Lindane	0.1	5.3±.3	0.3	7.9±.5
Check	0.0	7.5±.3	—	9.0±.1

Table 3.—Summary: the effect of alkaline and acid soil on the flavor of canned tomatoes.[1]

	Alkaline Soil						Min. Sig. Dif.[2]
	A	B	C	D	E	F	
Mean	4.6	4.4	3.0	6.7	5.3	7.3	1.3
	Acid Soil						
	G	H	I	J	K	L	
Mean	4.8	4.7	2.3	6.3	5.6	6.9	1.3

[1] Treatments as noted in table 1.
[2] Minimum significant difference at the 1 per cent level.

ride preparations were to be so classified; the lindane materials, while not generally associated with mustiness, were associated with off-flavor. The tomatoes from the second picking were given virtually the same scores as tomatoes from the first picking, 16 days earlier.

The results from the benzene hexachloride residue analyses showed that samples treated with technical benzene hexachloride and lindane contained 0.6 ppm. and 0.1 ppm. of benzene hexachloride, respectively (Table 2). Thus, the musty flavor was associated with the higher residue, and the off-flavor with the lower residue. This agrees with Smith *et al.* (1949), who reported an apparent correlation between the amount of residue and intensity of off-flavor in peaches sprayed with technical benzene hexachloride.

It was indicated rather conclusively that there was no difference in taste in samples grown on alkaline or acid soil (Table 3).

Potato investigations.—The judges participated in two sessions to evaluate treatments; the results of their scorings are summarized in table 4.

Considering both sessions, the mean scores again fell into two general categories. In one group, the samples received lindane preparations, and in the other group, the samples received the technical

Table 4.—The effect of benzene hexachloride treatments on the flavor of canned potatoes[1]: mean scores of two taste panel sessions held on the same day.

	First Session								Min. Sig. Dif.[2]
	A	B	C	D	E	F	G	G*	
Mean	6.7	5.9	6.3	7.7	8.0	7.4	8.8	9.9	2.0
	Second Session								
	H	I	J	K	L	M	N	N*	
Mean	7.0	6.9	6.3	8.1	7.4	6.0	9.1	9.9	1.9
	Both Sessions								
	A,H	B,I	C,J	D,K	E,L	F,M	G,N	G*,N*	
Mean[3]	6.9±.5	6.4±.5	6.3±.5	7.9±.5	7.7±.4	6.7±.4	9.0±.3	9.9±.1	

[1] The treatments were as follows:
A,H —Technical benzene hexachloride
B,I —Technical benzene hexachloride stabilized
C,J —Technical benzene hexachloride stabilized and washed
D,K —Pure gamma benzene hexachloride (lindane)
E,L —Pure gamma benzene hexachloride stabilized and washed (lindane)
F,M —Distilled technical benzene hexachloride dust
G,N —Check, untreated
G*,N*—Check, untreated; sample made known to judges
[2] Minimum significant difference at the 1 per cent level.
[3] Standard Error included.

benzene hexachloride formulations. The lindane-treated samples were distinguished by the fact that none was significantly different from the untreated check, and all but one of the technical benzene hexachloride-treated samples were characterized by being different from the untreated check at the 1 per cent level of significance. The groups were not significantly different from each other, nor were the members within the groups significantly different from each other.

The data obtained from the study of the effect of soil type on flavor contamination showed no difference between the samples grown in the two types of muck soil (Table 5).

To summarize, the data on the potato taste panel indicated that the lindane preparations were superior to the technical benzene hexachloride preparations. While the data indicated that the lindane formulations were not statistically different from the untreated checks, they also indicated that off-flavor persisted under the rigorous conditions in which these tests were conducted.

The results from the residue analyses showed that samples treated with technical benzene hexachloride contained more benzene hexachloride as a residue (Table 2) and the results from the taste tests showed that these samples also had more objectionable flavor.

Perhaps worthy of note was the criticism some of the judges volunteered after they had tasted both the tomatoes and potatoes. It was their opinion that the potatoes were "more difficult to taste" because the off-flavor was apparently not perceived immediately but rather slowly. Furthermore, there was more of a tendency for this off-flavor or musty taste to remain in the mouth (even after several rinses with distilled water) than with other products which they had tasted. This is in accordance with the statement of Greenwood (1949) that some tasters found that the flavor of benzene hexachloride persisted as long as 2 or 3 hours. Davis (1948) reported the same reaction with peaches treated with this material.

SUMMARY AND CONCLUSIONS.—New formulations of technical benzene hexachloride and lindane were tested on tomatoes and potatoes grown in acid and alkaline soils in the greenhouse in an effort to investigate possibilities of eliminating objectionable qualities. The materials were used in soil treatments at the rate of 2 pounds of the gamma isomer per acre, and also in supplementary spray treatments at the rate of 3 ounces of the gamma isomer per 100 gallons of water. Five spray treatments were applied to each crop, and residues accumulated heavily on the foliage since no wash-off occurred during the period of the tests.

A taste panel composed of 8 to 10 experienced judges tasted the treated products after they had been canned and stored for a short period. The panel judged the tomatoes grown in acid soil (pH 5.3) as being no different from the fruit grown in alkaline soil (pH 7.6). The soil pH also had no influence on the flavor of potatoes when they were grown in soils having a pH of 5.6 and 7.5.

The panel judged the tomatoes treated with technical benzene hexachloride as tasting musty; all of these treatments were significantly different from the untreated check. While the technical benzene hexachloride-treated potatoes were

Table 5.—The effect of alkaline and acid soil on the flavor of canned potatoes[1]

	Alkaline Soil								Min. Sig. Dif.[2]
	A	B	C	D	E	F	G	G*	
Mean	6.8	7.0	7.2	7.9	7.6	6.3	9.9	10.0	0.6
	Acid Soil								
	H	I	J	K	L	M	N	N*	
Mean	7.0	6.9	7.5	7.6	6.8	6.7	9.7	9.9	0.6

[1] Treatments as noted in table 4.
[2] Minimum significant difference at the 1 per cent level.

not judged musty, they were definitely off-flavor and were also significantly different from the untreated check. The lindane-treated tomatoes were associated with off-flavor but were not generally significantly different from the untreated check. Similarly, the lindane-treated potatoes, while being slightly off-flavor, were not significantly different from the untreated check.

Samples of the treated products were analyzed for residues and it was found that the products treated with technical benzene hexachloride had considerably more residue than the products treated with lindane. There appears to be a strong correlation of residue content with flavor contamination. It was indicated that off-flavor in potatoes may be more difficult to perceive than it is in tomatoes, the amount of residue being equal.

While the dosages used in these experiments would probably not be excessive in the field, the fact that they were used under greenhouse conditions makes them excessive.

LITERATURE CITED

David, Lyle H. 1948. Benzene hexachloride in processed peaches. Food Pack. **29**(8): 35–6, 70.

Greenwood, Mary L. and J. M. Tice. 1949. Palatability tests on potatoes grown in soil treated with the insecticides benzene hexachloride, chlordane, and chlorinated camphene. Jour. Agr. Res. **78**(11): 477–82.

Hoskins, W. M. 1949. How pest control programs affect residues in foods. Agr. Chemicals **4**(10): 22–7, 77–8.

Rohwer, S. A. 1949. Initial flavor and odor studies with benzene hexachloride. Agr. Chemicals **4**(8): 35, 75.

Smith, Clyde F., Ivan D. Jones, and J. A. Rigney. 1949. Effect of insecticides on the flavor of peaches —1948. JOUR. ECON. ENT. **42**(4): 618–23.

Tressler, C. J., Jr. 1947. The recovery of DDT from canned foods and its stability during processing. Jour. Assoc. Off. Agr. Chem. **30**(1): 140–4.

Rate of Penetration of Oxygen Through Layers of Petroleum Oil

WALTER EBELING[1]

The rate of penetration of oxygen through uniform layers of petroleum oils of different physical and chemical properties was investigated as having a possible relation to insecticidal effectiveness.

PROCEDURE.—Fifty ml. of alkaline pyrogallol, prepared by combining 1 volume of 22 per cent pyrogallol with 6 volumes of 60 per cent potassium hydroxide, was poured into a 500 ml. wide-mouth erlenmeyer flask with ground glass female joint. Ten ml. of petroleum oil was added to the flask, producing a layer 1.4 mm thick floating on the alkaline pyrogallol solution. A mercury manometer with a sliding millimeter scale was fitted into the mouth of the flask and the union was sealed with sealing grease.

The oxygen penetrating through the layer of oil was, of course, absorbed by the reducing agent below the oil. The rate of penetration of oxygen through the layer of oil was determined by recording at suitable intervals the progress of the column of mercury in the manometer.[2]

Two sets of the above equipment were used in the experiment. They were housed in an insulated box, 15 by 14 by 24 inches, equipped with an electric light bulb and thermostat to maintain a temperature of 80° F.

THE OILS USED IN THE EXPERIMENT.—Some of the physical and chemical properties of the oils used in the experiment are shown in table 1. It will be noted that the series of 13 oils includes fractions of widely different physical properties, with a considerable range of unsulfonated residue, and of both asphaltic base and paraffinic base.

The original intention had been to test

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[2] Although it is known that even highly refined petroleum oils will oxidize to some extent (Johnson 1948, Unpublished thesis, Univ. of California, Berkeley), no manometrically measurable loss of oxygen from this source was noted in the present series of experiments when the oils were placed alone in the flask.

a large number of oils in order to determine the differences between oils having a similar specific gravity and distillation range but differing in per cent of unsulfonated residue (U.R) or in paraffinicity, or between oils having a similar U.R. or similar degree of paraffinicity, but differing in certain physical properties. It was hoped that oils from different wells within a single oil field or from oil fields from widely separated regions could be tested. Because of a change in research projects, the experiment could not be continued as originally outlined. The preliminary data presented will serve primarily as a demonstration of the adequacy of the technique employed.

RESULTS.—Oil No. 1 was a California oil meeting the state requirements of a light medium spray oil. In all tests this oil was used as the standard with which one of the other oils was compared. However, four trials were first made in which oil No. 1 was placed in each of the two flasks so that the range of error in the technique could be determined. Manometer readings were made several times a day for about 5 or 6 days. The close agreement in the operation of the two sets of equipment (A and B) with identical oils is shown by a comparison in the final readings of the manometers:

FINAL MANOMETER READINGS IN MM. Hg, USING IDENTICAL OILS IN EACH APPARATUS

APPARATUS	Trial 1	Trial 2	Trial 3	Trial 4
A	45	50	46	58
B	45	49	46	57

The above trials showed that any substantial difference in the manometer readings if different oils were used would be a dependable measure of the difference in the rate of penetration of oxygen through the oil layers. Nevertheless, each of the 12 trials made in the experiment was repeated to determine whether the difference in manometer readings could be caused by leaks which might have developed in the apparatus after the first trials were made. In all cases the results of the second trial were closely similar to those of the first.

The results of the experiment are graphically presented in Figure 1. Because of fluctuations in barometric pressure and an unavoidable fluctuation of 3° F. in temperature, the points shown on the graphs show a corresponding fluctuation from the theoretical curve.

The most definite correlation that can be established from the limited data is the inverse relation of rate of penetration of oxygen to specific gravity (and distillation range). Compare, for example, the penetration curve for light medium oil with the curve for heavy spray oil (graph A) and light spray oil (graph B). The most rapid penetration of oxygen took place with the oils of lowest specific gravity (numbers 4, 9, and 10). Reversals of this tendency are seen in G and K. In G the slower penetration of oxygen with the oil of lower specific gravity might be explained by the lower per cent of unsaturated hydrocarbons in the latter (99 per cent U.R.). It is likely that oxygen would dissolve in saturated hydrocarbons less rapidly than in the unsaturated hydrocarbons. Note for example that oil No. 3 has the same specific gravity as oil No. 7, but when compared with oil No. 1 (B), it is considerably more impervious to oxygen than oil No. 7 (F). This may be due to the much lower U.R. (and correspondingly higher content of unsaturates) in the latter oil. On the other hand, oxygen penetrated much more slowly in oil No. 13 (L) than in oil No. 1 despite the fact that oil No. 13 had the lowest U.R. (73.2) of any oil used in

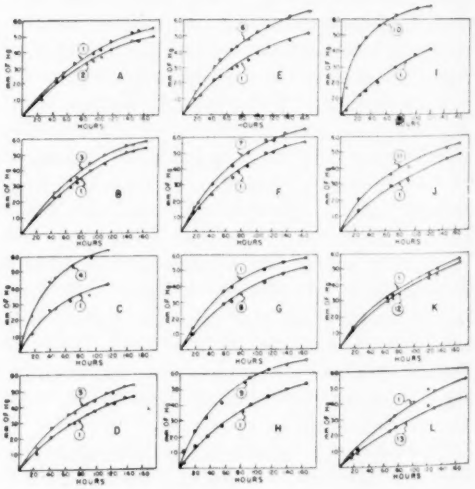

FIG. 1.—Curves showing the rates of penetration of oxygen through 1.4 mm layers of widely differing petroleum oils (Nos. 2 to 13) as compared to a light medium spray oil (No. 1). See table 1 for the properties of the oils.

Table 1.—Specifications of oils used in penetration experiments.

Oil Number	Specific Gravity 60/60° F.	Temperature (° F.) for tillation of 5%	90%	Viscosity	Per Cent Unsulfonated Residue	Base
1	0.885	582	693	71	92	Asphaltic
2	0.889	628	706	94	94	Asphaltic
3	0.882	554	688	61	92	Asphaltic
4	0.824	430	686	44	98	Paraffinic
5	0.870	577	760	65	97	Asphaltic
6	0.864	562	731	94	81	Paraffinic
7	0.882	531	719	95	80	Asphaltic
8	0.874	620	745	60	99	Asphaltic
9	0.823	502	570	41	91	Paraffinic
10	0.808	348	468	32	96	Asphaltic
11	0.826	522	702	58	81	Paraffinic
12	0.876	584	736	76	93	Asphaltic
13	0.908	616	734	102	73	Asphaltic

the experiment. The specific gravity, however, was 0.013 higher than that of oil No. 1. Likewise, the slightly slower penetration of oxygen in oil No 12 as compared to oil No. 1 (see K) is the reverse of what one would expect from the relative specific gravities of the two oils, yet this reversal probably cannot be explained on the basis of U.R., for the U.R. of the two oils is almost identical.

There are not sufficient data from this experiment to indicate any difference in the rate of penetration of oxygen between asphaltic and paraffinic oils. To make a reliable experiment on this aspect of the problem, oils of different paraffinicity would have to be found which are similar in their physical properties, with the exception of viscosity, and possibly also similar in the per cent of unsulfonated residue. Such a series of oils was not available for the present experiment.

POSSIBLE RELATION TO INSECTICIDAL EFFECTIVENESS.—Among oils which differ with respect to the rate of penetration of oxygen, the *a priori* assumption might reasonably be that those that have the greatest ability to exclude oxygen from a treated insect would be the most effective insecticides. The reverse was shown to be the case, however, in experiments reported in a previous paper (Ebeling 1945). Potato tuber moth larvae, *Gnorimoschema operculella* (Zeller), and adults of the California red scale, *Aonidiella aurantii* (Maskell), were immersed in spray oil and some individuals were removed and placed on blotting paper to remove excess oil. These died much more rapidly than those insects which were left with a heavy film of oil or completely immersed in oil. Yet in the case of the latter insects, the oxygen would be more completely excluded.

SUMMARY.—A technique was devised for the comparison of the rates of penetration of oxygen through layers of oil of different physical and chemical properties. A preliminary test with 12 oils of widely different physical and chemical properties showed a general inverse relation of oxygen penetration to specific gravity. The effect of the per cent of unsulfonated residue and degree of paraffinicity could not be determined from the limited number of oils tested.

This paper is intended primarily as a description and evaluation of the technique employed.

No implication that oils more impervious to oxygen would be more effective insecticides is intended, for experiments reported in a previous paper indicate that, at least within limits, just the opposite may be the case, provided all other factors are constant.

LITERATURE CITED

Ebeling, W. 1945. Properties of petroleum oils in relation to toxicity to potato tuber moth larvae. JOUR. ECON. ENT. **38**(1): 26–34.

1948. The influence of petroleum spray oils and their oxidation products on the metabolism of bean leaves. Dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy. On file in the Library of the University of California, Berkeley, California.

Aerial Spray Tests on Adult Salt-Marsh Mosquitoes Resistant to DDT[1]

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Early in June 1949 observations in Brevard County, Fla., indicated that the usual aerial spraying of DDT was not controlling larvae or adults of salt-marsh mosquitoes, *Aëdes taeniorhynchus* (Wied.), and *A. sollicitans* (Wlkr.), so well as in previous years. This was noticed particularly in the vicinity of Cocoa Beach, where DDT had been applied on a small scale as early as 1943 and 1944, and extensively since 1945. A program of study was therefore outlined to determine whether the mosquitoes were developing a resistance to DDT or whether other factors were responsible for the poor control.

Observations on the actual control operations in the county indicated that the materials and method of application were not at fault. It appeared, therefore, that mosquitoes in the area had developed some degree of resistance to DDT. This belief was soon confirmed by laboratory studies of the susceptibility of larvae and adults from treated and untreated areas (unpublished data). Field tests were then conducted in the treated area to obtain information on the relative effectiveness of DDT and other insecticides against the adults of these two species. The results, together with the data obtained on practical control operations, are given in the present report.

Mosquito Control Operations in Brevard County.—A number of different marsh areas in the vicinity of Cocoa Beach were observed to determine by adult landing counts the actual effectiveness of routine and special spraying operations. The plots were located on a narrow peninsula and included both open marshes covered with pickleweed, *Batis maritima* L., and salt-marsh bermuda, *Distichlis spicata* (L.), and adjacent wooded areas where trees and undergrowth formed a canopy. Landing counts were made in wooded areas where *Aëdes taeniorhynchus* usually predominates, and on the open marshes where *A. sollicitans* is the predominant species. Counts before treatment and at 6 and 24 hours after treatment were made by two men at a number of places in each plot.

The DDT spray formulations used are shown in table 1. Most of the plots were treated at the rate of 0.2 pound of DDT per acre with a 5 per cent DDT-fuel oil solution. One plot each was also treated with a 10 or 20 per cent oil solution or a 5 or 10 per cent emulsion to determine the effectiveness of different formulations and concentrations of DDT. In a few tests a small amount of pyrethrins or other insecticides was added to a 5 per cent DDT solution to activate the mosquitoes. The sprays were applied at the rate of 2 quarts per acre by county planes (PT-17) equipped with under-wing spray booms. The planes operated at a height of 15 to 25 feet over the open marshes and just over the tops of the trees in wooded areas —60 to 100 feet. Swath intervals varied somewhat, but for the most part they were 100 feet or less.

None of the treatments provided consistently effective control against either species (Table 1). In a majority of the plots the treatments gave somewhat higher control of *Aëdes sollicitans* than of *A. taeniorhynchus*, presumably because more spray reached the ground in open areas than in wooded areas. The control of *A. taeniorhynchus* ranged from 0 to 91 per cent 6 hours after treatment and averaged only 59 per cent, whereas with *A. sollicitans* the control ranged from 32 to 97 per cent and averaged 77 per cent. Two treatments with 10 per cent DDT sprays gave no better control than those with 5 per cent solutions, but one application of 20 per cent solution (0.8 pound of DDT per acre) showed 96 per cent reduction of *A. sollicitans* at 6 hours. Similar results on this species were also obtained with a 5 per cent DDT solution in one test in which 0.03 per cent of pyrethrins was added (1 pint of a 20-per cent extract to

[1] Presented at the meeting of the American Association of Economic Entomologists at Tampa, Fla., December 13–16, 1949.

[2] U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine, under funds allotted by the National Military Establishment.

[3] Director of the Brevard County, Fla., Mosquito Control District.

[4] J. A. Fluno, A. N. Davis, C. I. Mooney, and E. Nottingham assisted in making these tests.

Table 1.—**Effectiveness of aerial spraying operations conducted by the Brevard County Mosquito Control District with various DDT formulations for control of adult salt-marsh mosquitoes. (Counts are averages of adults on 2 men after 1 minute at several places in each area.)**

DDT Formulation	Dosage (Pounds per Acre)	Pretreatment Count[1]		Per Cent Reduction in—			
				6 Hours		24 Hours	
		A. sollicitans	*A. taeniorhynchus*	*A. sollicitans*	*A. taeniorhynchus*	*A. sollicitans*	*A. taeniorhynchus*
5% in fuel oil	0.2	105	20	86	65	59	60
		—	47	—	66	—	34
		46	45	87	91	52	38
5% in fuel oil+0.3% of chlordane	.2	75	28	97	82	79	64
		40	60	82	—	15	—
5% in fuel oil+0.3% of a thiocyanate[2]	.2	28	28	82	0	29	11
5% in fuel oil+0.03% of pyrethrins	.2	46	41	96	44	65	54
10% in fuel oil+aromatic petroleum solvent[3]	.4	—	46	—	56	—	54
20% in fuel oil+aromatic petroleum solvent[3]	.8	43	—	96	—	63	—
5% emulsion (from concentrate containing 25% of DDT, 10% of an aralkyl polyether alcohol,[4] and 65% of xylene)	.2	31	50	32	70	0	61
10% emulsion	.4	21	64	38	59	0	42
Average	—	—	—	77.3	59.2	40.2	46.2

[1] *Aëdes sollicitans* counts were made in open marsh areas and *A. taeniorhynchus* counts in wooded areas.
[2] 2-(2-butoxyethoxy)ethyl thiocyanate.
[3] *Sovacide 544 C.*
[4] *Triton X-100.*

80 gallons), and in another test in which 0.3 per cent of chlordane (1 quart to 80 gallons) was added. In none of these tests, however, was the high reduction maintained for 24 hours and the tests were not replicated. In several instances repeated applications of 5 per cent solutions to the same area failed to give such satisfactory results as were obtained formerly with a single application.

On July 21 the entire area from several miles south of the Banana River Military Reservation to a point 10 miles north was sprayed with a C-47 plane operated by the Air Force aerial spraying unit. A 20 per cent DDT-oil solution was applied at the rate of 0.6 pound of DDT per acre. A large brood of *Aëdes sollicitans* emerged on July 19 and 20 and extensive migration evidently occurred after the spraying on July 21, the 6-hour counts being as high or higher than the pretreatment counts, which in this case were made 2 days before the treatment. A part of the area was resprayed on July 22 at 0.4 pound of DDT per acre, and the average 6-hour post treatment count in open marshes was 9 compared with 100+ or higher on the previous day. These data are not included in the table as they were incomplete.

AIRPLANE SPRAY TESTS WITH VARIOUS INSECTICIDES.—Aerial spraying tests with DDT and other insecticides were started in the Cocoa Beach area early in August and continued until late in September. Insecticides for the tests were furnished by the Army Quartermaster Corps. In the first series (on Aug. 8) approximately 3,000 acres were sprayed with a 20 per cent DDT-oil solution at the rate of 0.3 pound of DDT per acre. The applications were made with a C-47 plane operated by the Air Force spraying unit from Langley Field, Va. The same plane was also used to treat two plots with 20 per cent chlordane-oil solution, one of about 2,000 acres at the rate of 0.3 pound, and another of about 600 acres at the rate of 0.6 pound per acre. Single plots of about 160 acres each were sprayed with lindane and dieldrin at rates of 0.1 and 0.3 pound per acre. These applications were made with Stearman (PT-17) planes owned by the Brevard County Mosquito Control District.

Three other series of tests were also run on plots about 160 acres in size, and the treatments were applied with the County Stearman planes. In these tests DDT, chlordane, and toxaphene were applied at the rate of 0.2 pound per acre; technical benzene hexachloride (12 per cent gamma isomer) at 0.2 and 0.4 pound; and lindane, dieldrin, and parathion at 0.05 and 0.1 pound per acre. One test was also made with lindane at 0.025 pound per acre in the third series.

All the materials were applied as oil solutions at the rate of 2 quarts per acre, the concentration of insecticide being varied to give the required dosages (*i.e.*, a 2.5 per cent solution for a dosage of 0.1 pound of insecticide per acre, and other dosages in proportion).

Adult mosquito counts were taken on each of 2 men at 10 or more stations in each plot, the counts being averaged to give the landing rate per man per minute. Counts were made the day before treatment, and at 6, 24, and 48 hours after treatment. Wherever possible, half the counting stations were located in open marsh where *Aëdes sollicitans* usually predominated, and half in wooded areas where the adults were chiefly *A. taeniorhynchus*. At the time of the second series of tests, however, a new brood had recently emerged and active migration was under way. *A. sollicitans* was recorded in large numbers in the woods as well as in open areas the day before treatment. *A. taeniorhynchus* was relatively scarce at that time, but large numbers were present in nearly all plots at 6 and 24 hours after treatment. For this reason the counts indicated no control at all of this species. To obviate as much as possible the effect of migration from untreated areas, the test plots were laid out so as to form a continuous strip. Representative check plots were not available, therefore, but past experience has indicated that fluctuations in the mosquito populations are not ordinarily large within 6 or even 24 hours, except during periods of general dispersion such as occurred in the second series.

The results obtained with the various treatments are given in table 2. Lindane was the most effective material, and gave good control of both species in two tests at a dosage of 0.1 pound per acre. At 0.3 pound per acre it showed complete effectiveness at the 6-hour count and 97 to 99 per cent reduction after 24 hours. The 6-hour counts also showed good control of *Aëdes sollicitans* in four plots at a dosage of 0.05 pound, but one treatment at 0.025 pound was ineffective. Technical benzene hexachloride at 0.2 and 0.4 pound per acre gave results that compared favorably with lindane at 0.05 and 0.1 pound per acre in the open marshes, but was somewhat less effective in the woods. Dieldrin in the first series was about equal to lindane at the same dosages. In the second and third series at dosages of 0.1 and 0.05 pound, the results were less favorable with dieldrin. Parathion, which was tested only in the fourth series, gave good reductions of *A. sollicitans* at dosages of 0.1 and 0.05 pound, but again was much less effective in the woods.

Chlordane and DDT gave variable results, and neither material was highly effective in most tests at dosages of 0.2 and 0.3 pound per acre. A 0.6-pound dosage of chlordane showed excellent results at the 6-hour count, but the reduction was only 79 to 88 per cent after 24 hours.

As previously mentioned, the second series of tests was carried out during the period of dispersion of a new brood of mosquitoes. *Aëdes taeniorhynchus* apparently emerged a day or so later than *A. sollicitans*, and migration into the treated plots was heavy after the spraying was completed, all except one plot showing an increase of *A. taeniorhynchus* instead of a reduction. In the other series the population appeared to be more settled and, in view of the size of the treated areas, little infiltration into the plots within 24 hours was to be expected. In many of the tests, however, the 24-hour posttreatment counts were considerably larger than the 6-hour counts, and it is possible that at least a part of this larger count is attributable to the recovery of knocked-down mosquitoes.

Except in the first series of tests, satisfactory control of *Aëdes taeniorhynchus* in the woods was not obtained with any of the treatments. Since this is usually the principal species in most of the Florida coastal area, further tests will be required to determine the effective dosages in woods. In this connection, attention may be called to previous aerial tests in wooded areas carried out by the Orlando, Fla., laboratory in 1946 (Fluno *et al.* 1949). In these tests the results with DDT were considerably better than in the present tests against *A. taeniorhynchus*, but with benzene hexachloride, toxaphene, and chlordane they were similarly ineffective at comparable dosages.

SUMMARY.—Observations in the Cocoa Beach area of Brevard County, Fla., indicated that aerial application of DDT at the rate of 0.2 pound per acre was not giving as good control of salt-marsh mosquitoes, *Aëdes taeniorhynchus* (Wied.) and *A. sollicitans* (Wlkr.), as in previous years. Higher concentrations of DDT also failed to be consistently effective,

Table 2.—Results of aerial spray tests with different insecticides for the control of adult salt-marsh mosquitoes in marshes and in woods. Brevard County, Fla.

Material Used	Dosage (Pound per Acre)	Plot[1]	Pre-treatment Count		Per Cent Reduction in—			
					6 Hours		24 Hours	
			A. sollicitans	*A. taeniorhynchus*	*A. sollicitans*	*A. taeniorhynchus*	*A. sollicitans*	*A. taeniorhynchus*
		First series—August 8						
DDT	0.3	South air base	307	0	—	—	89	—
		Sandspur	125	0	94	—	85	—
		Cocoa Beach	53	250	4	84	65	63
Chlordane	.3	South Yoder	114	72	87	94	59	73
	.6	North Yoder	97	250	91	99	79	88
Lindane	.1	Plot III	9	31	98	98	87	92
	.3	Plot I	106	115	100	100	99	97
Dieldrin	.1	Plot II	19	36	97	95	84	93
	.3	Plot IV	65	132	96	99	89	94
		Second series—September 6						
DDT	.2	South Yoder—marsh	247	5	93	+[2]	59	+
		woods	49	15	92	+	91	+
Chlordane	.2	Cocoa Beach—marsh	386	0	76	—	+	—
		woods	215	10	+	+	+	+
Toxaphene	.2	Plot V—marsh	240	0	80	—	+	—
		woods	45	6	41	+	68	+
		Cocoa Beach (town)	39	0	79	—	54	—
Technical benzene hexachloride	.2	North Yoder—marsh	178	0	98	+	90	+
		woods	35	6	96	+	92	+
	.4	South causeway—marsh	415	0	91	+	76	+
		woods	35	28	99	+	—	+
Lindane	.05	North causeway—marsh	19	—	95	—	52	—
		woods	268	3	97	+	—	+
		Air Base	90	0	98	—	61	—
	.1	Plot II—open	300	0	99	—	95	+
		woods	19	21	93	93	95	57
Dieldrin	.05	Plot IV—marsh	300	0	26	—	+	+
		woods	13	4	75	+	63	+
	.1	Plot III—open	13	5	84	58	68	+
		woods	23	5	91	29	84	+
		Third series—September 13						
DDT	.2	South Yoder	40	90	88	60	89	83
Technical benzene hexachloride	.2	Plot II	56	32	92	96	59	78
		Plot V	161	15	99	64	93	23
	.4	Plot IV	155	10	99	75	95	64
Lindane	.025	North Yoder	37	103	78	34	46	72
	.05	South causeway	138	106	94	82	90	80
		South air base	224	0	99	—	96	—
Dieldrin	.05	North causeway	215	178	81	76	94	66
		Cocoa Beach	84	173	71	61	70	74
		Fourth series—September 22–23						
DDT	.2	Plot IV	65	18	61	47	79	4
Technical benzene hexachloride	.2	South causeway	90	131	96	62	89	20
	.4[3]	North causeway	74	85	91	73	92	38
	.4[4]	Cocoa Beach	73	263	98	93	92	87
Parathion	.05	North Yoder	27	158	97	86	88	21
	.1	South Yoder	17	73	80	48	84	30
	.1	South air base—marsh	98	—	100	—	90	—

[1] *A. sollicitans* usually occurs in open marsh areas during the daytime and *A. taeniorhynchus* in wooded areas, but in the second series of tests migration was under way and the two species were intermingled.
[2] Plus sign indicates an increase in the posttreatment counts.
[3] 5% solution applied at 4 quarts per acre.
[4] 10% solution applied at 2 quarts per acre.

and the evidence indicated that the mosquitoes in this area, after several years of intensive treatment, had developed some degree of resistance to DDT. This belief was soon confirmed by laboratory tests of the susceptibility of larvae and adults from treated and untreated areas (unpublished data). Several series of airplane spray tests were then carried out in the Cocoa Beach area to evaluate the effectiveness of lindane, technical benzene hexachloride (12 per cent gamma isomer), toxaphene, parathion, chlordane, and dieldrin against adult salt-marsh mosquitoes, and to determine whether any of these materials would be satisfactory substitutes for DDT.

DDT and chlordane gave variable

results and neither material was highly effective in most tests at dosages of 0.2 and 0.3 pound per acre. A 0.6-pound dosage of chlordane showed excellent results at the 6-hour count, but the reduction was only 79 to 88 per cent after 24 hours. Lindane was the most effective, and gave good control of both *Aëdes sollicitans* in open areas and *A. taeniorhynchus* in woods at 0.1 pound per acre. Technical benzene hexachloride at 0.2 and 0.4 pound per acre gave results comparable to lindane at 0.05 and 0.1 pound per acre on the open marshes, but was less effective in the woods. The results with dieldrin at 0.1 and 0.05 pound per acre were not quite so good as with lindane. Parathion gave good reduction of *A. sollicitans* at dosages of 0.1 and 0.05 pound, but was less effective against *A. taeniorhynchus* in the woods. Toxaphene appeared less effective than DDT.

LITERATURE CITED

Fluno, J. A., E. S. Raun, C. C. Deonier, and F. Faulkner. 1949. Comparative toxicity of DDT and some of the newer insecticides to adults of salt-marsh mosquitoes. Mosquito News 9(1): 15–8.

House Fly Control in Dairy Barns[1]

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New pharmacological findings on the toxicity of DDT to man, and the progressive increase in fly resistance to DDT necessitated the reopening and vigorous pursuit of studies on the control of house flies, *Musca domestica* L., in dairy barns. The work for the 1949 season included testing of both old and new materials, the appraisal of various methods of application, the determination of possible residues in milk from cattle in sprayed barns, and the correlation of fly abundance with bacterial counts in milk.

Field studies of the control of DDT resistant flies have been made by several workers. Gilbert *et al.* (1950) in Florida reported that chlordane emulsion at 100 mg. of toxicant per square foot was the most consistently effective treatment, showing 84 to 98 per cent control for 5 to 7 weeks or longer in all barns. DDT failed to give appreciable control in two of three barns. A mixture of chlordane and DDT was less effective than chlordane alone but was more effective than DDT alone. Methoxychlor and a mixture of DDT and methoxychlor were effective in some cases, but not in others. A 50 mg. dosage of lindane gave excellent control in three of four tests and was somewhat more effective than a 25 mg. dosage. Dieldrin gave excellent control of flies in most tests at dosages of 50, 25, and 10 mg. per square foot. Toxaphene at 200 mg. per square foot was highly effective as an emulsion, but was less effective in a wettable-powder spray. Treatments with 5 mg. of pyrethrins plus 50 mg. of piperonyl butoxide were relatively ineffective, and twice this dosage gave only fair control for 1 week. Simmons (1949)[2] in Georgia reported that 200 mg. per square foot of DDT technical or water-wettable methoxychlor, and combined deposits of DDT and methoxychlor provided one week control; 120 mg. DDT and 80 mg. chlordane gave 6 weeks control; 25 and 50 mg. lindane gave effective control for 4 and 8 weeks respectively; 100 and 200 mg. chlordane provided 10 weeks control; 12.5 and 25 mg. dieldrin gave 10 weeks control. Mosna (1949) in Italy first reported that 2 gr. per square meter chlordane gave 3.5 months; 2 gr. toxaphene provided 3 weeks control. March & Metcalf (1949) in California, making use of wettable powder formulations, reported that 20 pounds of actual DDT per 100 gallons of water generally provided no significant residual control of house flies; 20 pounds of methoxychlor gave excellent fly control for 1 week to 1 month; 20 pounds of toxaphene resulted in good clean up, but reinfestation was rapid; 20 pounds chlordane provided a varied effectiveness of from 1 to 4 weeks;

[1] This is a report on an investigation carried on by the Department of Entomology of the New York State College of Agriculture and financed in part by grants from the Cooperative G.L.F. Incorporated, and the Geigy Company Incorporated.

[2] Simmons, S. W. 1949. The resistance of flies to DDT. Presented at the meeting of the Am. Assoc. of Ec. Ent. at Tampa, Florida, December 13–16.

2 pounds of gamma isomer of benzene hexachloride provided 3 to 4 weeks control.

EQUIPMENT AND METHODS.—One hundred and forty-eight barns were treated with a sprayer which had a tank capacity of 150 gallons and a pump delivery rate of 7 to 10 gallons per minute at 400 pounds pressure. The spray rod used consisted of a cut-off[1] with 38 inches of 0.5 inch aluminum pipe attached, and then a 10 inch piece of 0.25 inch galvanized pipe connected to the aluminum pipe at a 45 degree angle. Two male nozzles,[2] numbers 5 or 6 dependent on the concentration of insecticide, were placed 10 inches apart on the galvanized pipe.

In the overall treatment and spot treatment methods the barn surfaces were wet to the point of run off with the pump set at 350 pounds pressure. With this amount of treatment, it was calculated that one gallon of spray mixture covered an area of 250 to 300 square feet. A calculated deposit of approximately 15 mg. of actual insecticide per square foot was obtained when 1 pound of insecticide was diluted in 100 gallons of water.

Thirteen barns were sprayed by the spot treatment method. This entailed treatment of the places where flies were most likely to rest in the barn, such as around calf pens, stanchions, windows, doors, manure conveyor tracks, electric wires and bulbs, posts and other objects where a heavy concentration of fly specks was observed.

Toxaphene was applied to six barns with an aerosol machine.[3]

The insecticides in the experiment included lindane, DDT, methoxychlor, chlordane, toxaphene, and ditolyl trichloroethane used alone and in various combinations.

The fly counting grill (Scudder 1947) and spot counting method were used to obtain fly population estimates. The fly counting grill worked well during the warm days, but it was found to have limitations on cool days when the flies were inactive and would not move onto the grill. For this reason the spot counting method gave a better estimation of the population regardless of the temperature, the position of the sun, and whether the sun was shining or not. In this method, all of the flies were counted on an area of 2 square feet in each of the following positions in the barn: (1) entrance on sunny side, (2) corner on sunny side, (3) window on sunny side, (4) stanchion at mid-point, (5) manger at mid-point, (6) gutter at mid-point, (7) ceiling at mid-point, (8) window on dark side, (9) corner on dark side, (10) entrance on dark side, (11) on cow. The total counts for all of the positions was used in estimating the fly populations.

Because of the wide variation of total counts between barns an attempt was made to describe the degree of control in three categories. The term "good control" was used to describe a barn having no flies to a very few. "Partial control" was used for a barn having a few flies but not objectionable numbers and then "no control" when the barn was swarming with flies. It was found that arbitrary limits of the total fly counts could be chosen to correlate well with the qualitative observation of these categories, so that the proper category could be assigned without personal bias. The categories of control classified as to the number of flies counted on 22 square feet of barn surface are: (1) 0 to 20 flies—"good control." (2) 21 to 90 flies—"partial control." (3) over 90 flies—"no control." In practice both categories "good control" and "partial control" include sufficient reduction of fly populations to give satisfactory results. Accordingly, the two categories are combined and the number of weeks of at least partial control given by the different replicates in each treatment were averaged, (Tables 1 and 2 under "Effective control") and these averages were used as the practical periods of effectiveness. In tables 1 and 2 under "Good control" are the averages of the period of good control for the different replicates for each treatment. The difference between "Good control" and "Effective control" in tables 1 and 2 is the period of "partial control."

The statistical analysis employed to compare the periods of effectiveness of the treatments was Student's method with argument 't' as modified by Livermore (1934). A statistically significant difference was found between any two average effective control periods differing by 2 or more weeks and having 3 or more

[1] *Bean Pistol Grip.*
[2] *"Tat."*
[3] *Todd Thermal Aerosol Machine.*

replicates, except for the difference between treatments of 6 and 12 pounds of chlordane. Although a 2 week difference was found significant, a longer period of control was found more desirable. Because of the large amount of work dairy farmers have in the summer, the opinion of many farmers was that a satisfactory treatment should give 4 weeks or more effective control.

The house fly control experiment in dairy barns began in early June. Since the barns treated at this time were only moderately infested with flies and the fly populations were building up, the treatments were kept separate and are listed in table 2. The barns treated in the latter part of June and following were swarming with flies and are listed in table 1. In drawing conclusions only the results listed in table 1 were used, since it was felt that they gave a better indication of the effectiveness of the different treatments in controlling heavy populations of house flies in dairy barns.

Residue analyses[1] were run on milk samples taken from barns treated with DDT or lindane. The Schecter *et al.* (1947) colorimetric method was employed for analyzing milk for DDT, and the Frawley & Davidow (1949) method as modified by Kimball & Tufts[2] for lindane.

An experiment was set up to determine possible correlation between fly abundance and bacterial count of milk. Bacterial counts[3] of milk were taken in seven barns six days previous to treatment and six days after treatment with lindane.

RESULTS AND DISCUSSIONS.—When barns were heavily infested with flies the following list of treatments gave effective control for an average of 0 to 2 weeks. (Table 1 under "Effective control"):

Actual material per 100 gallons of water

lindane 0.6 pounds as a wettable powder
toxaphene 0.24 pounds "fog" treatment of a 25 cow barn
DDT 12 pounds as an emulsion
DDT 30 pounds as a wettable powder
DDT 5 pounds as a wettable powder & lindane 0.25 pounds as a wettable powder
DDT 5 pounds as a wettable powder & lindane 1 pound as an emulsion
DDT 5 pounds as a wettable powder & ditolyl trichloroethane 2.5 pounds as a wettable powder
methoxychlor 30 pounds as a wettable powder

The following list of treatments provided control for an average of 2.1 to 4 weeks:

lindane 2 pounds as a wettable powder
lindane 4 pounds as a wettable powder
lindane 4 pounds as an emulsion by spot treatment
toxaphene 8 pounds as a wettable powder
toxaphene 8 pounds as an emulsion by spot treatment
methoxychlor 20 pounds as a wettable powder

The following list of treatments gave control for an average of over 4 weeks:

lindane 2 pounds as emulsion
chlordane 6, 12, and 24 pounds as an emulsion
toxaphene 8 pounds as an emulsion
toxaphene 16 pounds as an emulsion by spot treatment
DDT 3 pounds as a wettable powder & chlordane 6 pounds as an emulsion

When the barns were moderately infested with flies the following list of treatments gave effective control for an average of 0 to 2 weeks (Table 2 under "Effective control"):

Actual material per 100 gallons of water

DDT 12 pounds as a wettable powder

The following list of treatments gave control for an average of 2.1 to 4 weeks.

lindane 1 pound as a wettable powder
lindane 2 pounds as half wettable powder and half emulsion
toxaphene 4 pounds as an emulsion
DDT 3 pounds as a wettable powder
DDT 6 pounds as a wettable powder
DDT 5 pounds as a wettable powder & methoxychlor 5 pounds as a wettable powder
methoxychlor 5 pounds as a wettable powder
methoxychlor 10 pounds as a wettable powder
methoxychlor 20 pounds as a wettable powder

The following list of treatments provided control for an average of over 4 weeks:

lindane 2.5 pounds as a wettable powder

The treatments applied when the barns were moderately infested with flies in general provided a longer control period than the treatments applied when the barns were heavily infested with flies (Tables 1 & 2). It was felt that the treatments applied when the barns were heavily infested with flies provided a better indication of the effectiveness of the same. Thus the following comparisons are based on the results in table 1.

Emulsifiable formulations of lindane

[1] The authors gratefully acknowledge the work of B. Schmalzriedt, C. A. Streuli, D. V. Kohli, and T. Khammash on the analysis of the milk residues.

[2] Private communication.

[3] The authors are indebted to the Dairyman's League Cooperative Association, Incorporated, Laboratory Division, Syracuse, New York, for making the bacterial counts.

Table 1.—The average number of hours or weeks of good and of effective control after treatment of barns heavily infested with flies.

Barns	Toxicant	Formulation—(Lbs.100 Gals.)	Good Control (Weeks) Aver.	Min.	Max.	Effective Control (Weeks) Aver.	Min.	Max.
10	Lindane	2 W_P[1]	1.4	1	3	2.3	1	3
10	Lindane	2 E[1]	4.6	2	6	5.8	2	8
4	Lindane	4 W_p	2.8	2	4	3.3	3	4
2	Lindane	0.6 W_p	1.5	1	2	1.5	1	2
1	Lindane (spot)[2]	4 E	2	2	2	4	4	4
4	Chlordane	6 E	3	2	4	4.3	3	5
4	Chlordane	12 E	5.5	2	9	6.5	3	9
4	Chlordane	24 E	6.8	5	8	7	6	8
4	Toxaphene	8 W_P	1.6	48	2	2.1	48[4]	3
13	Toxaphene	8 E	4.1	1	8	4.5	2	8
6	Toxaphene (spot)	8 E	2	2	2	2.6	2	3
6	Toxaphene (spot)	16 E	4.3	1	6	5.6	2	7
6	Toxaphene (thermal)[3]	0.24	24[4]	24[4]	24[4]	24[4]	24[4]	24[4]
6	DDT	12 E	0.7	48	1	1.7	48[4]	2
4	DDT	30 E	1.3	48	2	2	1	3
4	DDT-chlordane	3 W_P+6 E	5.5	4	8	7.5	6	9
4	DDT-ditolyl trichloroethane	5 W_P+2.5 W_P	0.7	48[4]	1	1.3	1	2
4	DDT-lindane	5 W_P+ .25 W_P	0.7	48[4]	1	1.5	1	2
3	DDT-lindane	1 E	1.3	1	2	2	1	3
4	Methoxychlor	20 W_P	1.9	48[4]	5	2.3	48[4]	6
4	Methoxychlor	30 W_P	1.3	1	2	2	1	3

[1] Wettable powder (W_p) and emulsion (E).
[2] Spot treatment.
[3] The amount of toxaphene blown into a 25-cow barn by the Todd Thermal Aerosol Machine.
[4] Hours.
Note: A statistically significant difference was found between any two average effective control periods differing by 2 or more weeks and having 3 or more replicates, except for the difference between treatments of 6 and 12 pounds of chlordan.

Table 2.—The average number of hours or weeks of good and effective control after treatment of barns moderately infested with flies.

Barns	Toxicant	Formulation (Lbs./100 Gal.)	Good Control (Weeks) Aver.	Min.	Max.	Effective Control (Weeks) Aver.	Min.	Max.
4	Lindane	1 W_P[1]	2	1	3	3.5	2	5
9	Lindane	1 W_P+1 E[1]	2.6	1	3	3	3	3
1	Lindane	2.5 W_P	6	6	6	7	7	7
5	Toxaphene	4 E	1.8	1	2	3.6	2	4
4	DDT	3 W_P	1.5	0	2	2.3	48[2]	3
4	DDT	6 W_P	2	1	3	3	1	4
4	DDT	12 W_P	1.8	48[2]	5	1.9	48[2]	5
4	DDT-methoxychlor	5 W_P+5 W_P	1.8	1	2	2.5	2	3
4	Methoxychlor	5 W_P	0.8	48[2]	1	2.3	1	3
4	Methoxychlor	10 W_P	1.4	48	4	2.8	1	7
4	Methoxychlor	20 W_P	1.1	48	2	2.5	2	3

[1] Wettable powder (W_p) and emulsion (E).
[2] Hours.
Note: A statistically significant difference was found between any two average effective control periods differing by 2 or more weeks and having 3 or more replicates.

and toxaphene were found to be significantly better than wettable powder formulations. Two pounds of actual lindane as an emulsion provided 5.8 weeks control while the same as a wettable powder provided only 2.3 weeks. Eight pounds of toxaphene in emulsion form gave a control of 4.5 weeks while the same as a wettable powder gave 2.1 weeks. Thus the emulsifiable form of both lindane and toxaphene gave control periods twice those given by the wettable powder form.

Spot treatment with toxaphene saved approximately 40 to 50 per cent of ma-

Table 3.—DDT analyses of milk from barns treated with DDT. Concentrations as actual material per 100 gallons of water.

Concentrations	48 Hrs.	1 Wks.	2 Wks.	3 Wks.	4 Wks.	Maximum Single Sample
	Parts per Million					
3	.04	.06	.05	.02	.03	.11
6	.07	.02	.02	.08	.06	.24
12	.31	.21	.06	.08	.06	.79

Note: Analyses unreliable under 0.10 ppm. Three to five barns treated for each concentration.

Table 4.—Lindane analyses of milk from barns treated with lindane. Concentrations as actual material per 100 gallons of water.

Concentrations	48 Hrs.	1 Wks.	2 Wks.	3 Wks.	4 Wks.	Maximum Single Sample
	Parts per Million					
1	.1	0	0	.1	.2	.4
2	0	.1	.1	.1	.1	.4
4	.1	.1	0	0	0	.4

Note: Analyses unreliable under .40 ppm. Four barns treated for each concentration.

terial over the regular overall method of treatment. The data in table 1 indicate that spot treatment with the same concentration was less effective in controlling flies than the overall method. However, if the concentration was doubled so that approximately the same total amount of material was used as in the overall treatment the period of control was at least equal to the over-all treatment 5.6 weeks. It may therefore be possible by the spot treatment to obtain as good control as with the overall treatment with much less chance of accidental contamination of milk. Spot treatment of a barn had the additional advantage that it could be accomplished with a knapsack sprayer.

A control period ranging from 1.7 to 3 weeks was obtained when the barns were treated with DDT in concentrations varying from 3 to 30 pounds of actual DDT per 100 gallons of water (Tables 1 & 2). During the summers of 1945 to 1947 3 pounds of DDT provided 2 months control. Comparison of the two controls indicates that the house fly has become highly resistant to DDT over wide areas of New York State.

Combinations of DDT with methoxychlor, lindane, or ditolyl trichloroethane showed no significant increase in the control period over that given by DDT alone (Tables 1 and 2). Methoxychlor alone was not better than the DDT-methoxychlor combination. Lindane alone at higher dosages gave longer periods of control, so probably the poorer control given by lindane in combination with DDT is due to lower concentrations of the former. The mixture of chlordane and DDT was more effective than chlordane alone and was more effective than DDT alone (Tables 1 & 2).

In the "fog" treatments it was estimated that approximately 0.24 pounds of toxaphene was blown into each 25-cow barn. The "fog" killed most of the flies present at the time of application but 48 hours later the barns were again swarming with flies (Table 1).

From tables 3 and 4 it can be seen that insignificant amounts of DDT and lindane residues were found in milk for a period of 4 weeks, except for the 48 hour and one week analyses of milk from barns treated with 12 pounds of DDT and an occasional single sample with the lower concentrations of DDT. The data on DDT residues analyses agree favorably with the results of Harris *et al.* (1950), who also found insignificant amounts of DDT in milk during a period of 2 weeks when barns were treated with 10 pounds or less of DDT.

There was no detectable difference in the bacterial counts 6 days before and 6 days after the barns had been treated with lindane. Since the numbers of bacteria in milk are normally high and there is a large amount of variation between samples of milk, the number of bacteria the house flies added was not detectable.

Waste disposal for each barn was recorded and it was found to be normal for 149 barns and exceptionally good for 5 barns. There was not enough difference in this respect to show up any significant effect of sanitation on ease of fly control.

SUMMARY AND CONCLUSIONS.—Organic insecticides in various concentrations and formulations were used to treat 154 dairy barns. Results of the house fly control experiments in dairy barns for the summer of 1949 are as follows:

1. The treatments providing 4 weeks or more control of house flies in dairy barns which were heavily infested with house flies before treatment:

Actual material per 100 gallons of water

lindane 2 pounds as an emulsion
chlordane 6, 12, and 24 pounds as an emulsion
toxaphene 8 pounds as an emulsion

toxaphene 16 pounds as an emulsion by spot treatment
DDT 3 pounds as a wettable powder & chlordane 6 pounds as an emulsion

A list of treatments providing less than 4 weeks effective control are the following:

lindane 0.6, 2, and 4 pounds as a wettable powder
lindane 4 pounds as an emulsion by spot treatment
toxaphene 0.24 pounds "fog" treatment of a 25-cow barn
toxaphene 8 pounds as a wettable powder
toxaphene 8 pounds as an emulsion by spot treatment
DDT 12 pounds as an emulsion
DDT 30 pounds as a wettable powder
DDT 5 pounds as a wettable powder & lindane 0.25 pounds as a wettable powder
DDT 5 pounds as a wettable powder & lindane 1 pound as an emulsion
DDT 5 pounds as a wettable powder & ditolyl trichloroethane 2.5 pounds as a wettable powder
methoxychlor 20 pounds as a wettable powder
methoxychlor 20 pounds as a wettable powder

2. Emulsifiable formulations of lindane and toxaphene were found to be significantly better than wettable powder formulations.

3. When the concentration of toxaphene was doubled with the spot treatment method, approximately the same amount of toxaphene was used as in the overall treatment of a barn. Correspondingly the control period was at least equal to that of the overall treatment.

4. DDT in concentrations as high as 30 pounds per 100 gallons of water gave an average of only 2 weeks control of house flies in the field. This indicates the high resistance of the house fly to DDT in New York.

5. Combinations of DDT with methoxychlor, lindane, or ditolyl trichoroethane showed no significant increase in the control period over that given by DDT alone. Methoxychlor alone was not better than the DDT-methoxychlor combination. Lindane alone at higher dosages gave longer periods of control, so probably the poorer control given by lindane in combination with DDT is due to lower concentrations of the former. The mixture of chlordane and DDT was more effective than chlordane alone and was more effective than DDT alone.

6. Insecticidal treatment of barns for residual house fly control with the thermal aerosol applicator gave unsatisfactory results.

7. Insignificant amounts of DDT and lindane residues were found in milk for a period of 4 weeks, except for the 48 hour and 1 week analyses of milk from barns treated with 12 pounds of DDT and an occasional single sample with the lower concentrations of DDT.

8. The elimination of flies in dairy barns did not cause any detectable decrease in the bacteria count of milk.

LITERATURE CITED

Frawley, J. P. and B. Davidow. 1949. An ultraviolet spectrophotometric method for the quantitative estimation of benzene hexachloride in milk. Jour. Assoc. Official Agr. Chemists. **32**: 758–62.

Gilbert, H. I., H. G. Wilson, and J. M. Coarsey. 1950. Control of house flies in barns with different insecticides. U.S.D.A., B.E.P.Q. **E-795.**

Harris, H. J., E. J. Hansens, and C. C. Alexander. 1950. Determination of DDT in milk produced in barns sprayed with DDT insecticides. Agr. Chem. **5**(1): 51–2.

Livermore, J. R. 1934. The interrelations of various probability tables and a modification of Student's probability table for the argument 't'. Jour. Amer. Soc. Agron. **26**(8): 665–73.

March, R. B. and R. L. Metcalf. 1949. Laboratory and field studies of DDT resistant house flies in southern California. Bul. Dept. of Agr. State of Calif. **38**(2): 1–8.

Mosna, E. 1949. Octa-Klor, gammaesano e toxaphene usati contro le mosche DDT resistenti. Riv. di Parassitol. **10**(1): 31–51.

Pimentel, D. and J. E. Dewey. 1950. Laboratory tests with house flies and house fly larvae resistant to DDT. JOUR. ECON. ENT. **43**: 105.

Schechter, M. S., M. A. Pogorelskin, and H. L. Haller. 1947. Colorimetric determination of DDT in milk and fatty materials. Anal. Chem. **19**: 51–3.

Schwardt, H. H. 1946. Experiences in the use of DDT. Twentieth Annual Report of N. Y. State Assoc. of Milk Sanitarians: 161–65.

Scudder, H. I. 1947. A new technique for sampling the density of house fly populations. Public Health Reports. **62**(19): 681–86.

Barrier Strip and Pre-Flood Treatments with DDT to Control *Anopheles quadrimaculatus*

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The spraying of a strip of vegetation to provide an insecticidal barrier to protect the human population is a relatively new approach in the field of mosquito control. This measure could be applied to those breeding areas in which more conventional control methods would be impractical. Such barrier strips may be of two general types: (1) surrounding of temporary settlements such as encampments or troop concentrations in jungles, and (2) isolating mosquito breeding areas from the human population. In the first instance, essentially 100 per cent control must be obtained as the mosquitoes seek to penetrate the barrier for the method to be feasible. However, in the second case, those mosquitoes that do succeed in crossing the barrier must recross it as they return to oviposit, thus receiving a double exposure to the insecticide. Since it is assumed that only a small per cent of the adult population would succeed in initially crossing the barrier, only a few of those would succeed in returning to the breeding area. Therefore, it would be expected that the larval population would diminish quite rapidly following the treatment.

Three important factors require careful consideration and evaluation before this treatment should be made. The first factor involves a knowledge of the flight habits of the species to be confined or excluded, since these habits determine the height and depth of the barrier and its location with respect to the breeding area. It is conceivable that some species normally fly too high or make such extended flights that a barrier of reasonable proportions would not serve its intended purpose. The second of these involves the character of the surrounding vegetative screen. It must be sufficiently high so that the mosquitoes will fly through but not over it, and of sufficient depth so that they will alight once, and preferably several times, as they search for blood meals. Thirdly, a properly formulated insecticide of high order of toxicity and low repellency, capable of an extended period of residual action on foliage under the existing climatic conditions, must be available.

Madden *et al.* (1945) treated a 100-foot wide strip of vegetation and ground litter around a half-acre plot with a 5 per cent DDT-fuel oil solution applied at the rate of 10 gallons per acre. This treatment gave a 57 per cent reduction in the population of *Aëdes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.) within the barrier 27 days following the application. They suggested that wider barriers might prove to be more effective, especially against species which are less active. They stressed the importance of having knowledge of the resting habits of species against which this method is to be applied. Madden *et al.* (1945, 1947) also studied the effects of DDT formulations applied to foliage and to ground litter and observed little difference in degree of control. They also treated jungle growth with benzene hexachloride and DDT solutions, emulsions, and suspensions, with the latter proving to be most effective. Their over-all results indicated that application of residual sprays to vegetation is a potentially effective measure for mosquito control.

Experiments and Discussion.—The present studies were conducted at Blackwell Swamp, Wheeler Reservoir, in North Alabama. This area was selected because of its high anopheline breeding intensity and because a dense band of marginal vegetation bordered most of the breeding area. The shape of the barrier was that of an elongated horseshoe with the distance across the open end being about 600 feet. The breeding area, about 22 acres in extent, was primarily an old stand of tupelo gum, *Nyssa aquatica*, with an herbaceous understory consisting of plants such as lizard tail, *Saururus cernuus*, and coontail, *Ceratophyllum demersum*. The marginal vegetation consisted of a very dense band of willow, button ball, swamp red maple, greenbrier, blackberry, sweet gum, etc. from 50 to 100 feet wide.

The swamp had been drained during the previous year, but a small earth dam was placed across the ditch to maintain a fairly constant water level in the study

area. Prior to treatment, the area to be treated was marked in order to expedite spraying operations. An access road paralleled the margin of the projected treatment area so that heavy spraying equipment could be employed. The sprayer unit was an army surplus command car equipped with a gasoline engine and a positive displacement pump, and three 55-gallon drums for handling the spray materials. The physical set-up was such that the pump could be used to fill the tanks with water and mix the spray by circulation, as well as discharge the finished spray. The spray was discharged at 60 lbs. pressure through a nozzle with a 0.2 inch disk orifice.

Since it was desired that the toxic residue persist for a maximum time, a U. S. Public Health Service formulation consisting of a 25 per cent DDT, 63 per cent xylene, 2 per cent emulsifier,[1] and 10 per cent rosin (Anonymous 1948) was used after dilution at 1 part to 4 parts of water. The height and width of the barrier were arbitrarily set at 10 and 50 feet, respectively, since no detailed information on the initial flight habits of *Anopheles quadrimaculatus* was available. The rate of application was determined by spraying a test strip of dense vegetation 50 feet wide to a height of 10 feet with a definite volume of the emulsifier.[1] It was then calculated that 335 gallons of finished spray would be required per acre of barrier. The actual treatment rate averaged 325 gallons per acre, or 136.5 pounds of DDT per acre, or 1,420 mg. of DDT per square foot of ground covered. At first glance, this dose appears to be extremely excessive. However, Stanley (1945) found that during the maximum growth period of beans and tobacco the ratios of leaf area to ground area were 5.4 and 5.2, respectively, with only one surface of the leaves being considered. The areas of the stalks and stems also were not included in these ratios. If it is assumed in the present study that a ratio of five to one is a conservative approximation, the rate of application is therefore about 280 mg. per square foot which more nearly corresponds with the rate of 200 mg. per square foot recommended for residual treatments for the control of flies and mosquitoes.

The efficiency of the barrier was determined by dyeing approximately 5000 insectary-reared adult *A. quadrimaculatus* with 25 per cent Rhodamine B in soapstone and releasing them within the breeding area. A series of 19 adult checking stations were established in the vicinity and all mosquitoes were collected from them daily for 15 consecutive days and at weekly intervals thereafter until the first frost. The checking stations consisted of hollow trees, nail kegs, barns, and portable privy-type stations (Snow 1949). Certain of these stations were located within the breeding area, others around the periphery of the barrier, and still others some distance in the surrounding countryside. All *A. quadrimaculatus* collected were treated with alcohol and examined under an ultra-violet light for presence of the fluorescent dye.

The dyed mosquitoes were released late in the afternoon of September 6, and collections begun the following morning. A total of 6 marked mosquitoes were recovered, with 1 being taken the first day after release, 1 the second day, 2 the fourth day, 1 the ninth day, and 1 the twelfth day.

Four weeks prior to treatment, 11,007 adult *Anopheles quadrimaculatus* were collected from four stations near the breeding area over a 4-day period, but their numbers declined sharply in the interim so that no evaluation of the barrier can be made on the basis of the reduction of the natural population. Previous field studies in this area yielded from 0.06 to 20 per cent recovery of dyed adults with the average recovery being about 7 per cent. Goodwin (1949) secured a recovery of 5.8 per cent of marked *A. quadrimaculatus*. The 0.12 per cent recovery obtained in the present test suggests that the treatment was highly effective, but nevertheless the per cent recovery falls within the lower limit of recapture from an untreated area. Since there is considerable uncertainty as to the proper value of expected percentage recovery to be used, a clear-cut conclusion cannot be drawn as to the effectiveness of this treatment. However, if a five per cent recovery were applicable, the efficiency would be about 97 per cent since only 6 of the 250 expected adults were actually recovered.

The immediate effect of the treatment upon the larval and adult populations

[1] *Triton X-100.*

was to bring about their immediate reduction. Undoubtedly, some of the sprays

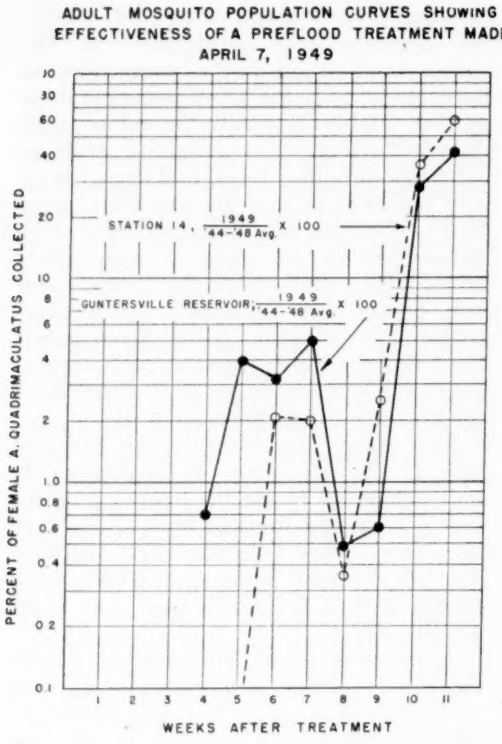
ADULT MOSQUITO POPULATION CURVES SHOWING EFFECTIVENESS OF A PREFLOOD TREATMENT MADE APRIL 7, 1949
PERCENT OF FEMALE A. QUADRIMACULATUS COLLECTED
STATION 14, 1949 / 44-48 Avg. X 100
GUNTERSVILLE RESERVOIR, 1949 / 44-48 Avg. X 100
WEEKS AFTER TREATMENT

FIG. 1.—Weekly *Anopheles quadrimaculatus* densities for Station 14 and Guntersville Reservoir, 1944–1949.

drifted out over the water and settled there, killing numerous larvae. This, of course, would affect the subsequent emergence of adults. Also, some adults were killed during the actual spray operation, even though it was carried out presumably after they had reached their diurnal resting places.

PRE-FLOOD TREATMENT.—The Tennessee Valley Authority water level management program for malaria control is based upon a four-phase schedule usually with low water levels in the early spring before the beginning of the mosquito breeding season. If a pre-flood or pre-oviposition treatment could be applied, it might be possible to reduce the populations of the early broods to such an extent that significant reductions in the adult population might occur over a considerable portion of the breeding season. Thus, the constant pool phase could be prolonged, and the amount of early airplane larviciding decreased.

A number of workers have demonstrated that pre-flood treatments with DDT can be of some value in the control of mosquitoes. Early experiments were carried out by Wisecup & Deonier (1945) and Horsfall (1946). McDuffie *et al.* (1949) and Rees *et al.* (1949) have recently completed projects involving this type of treatment.

EXPERIMENTAL AND DISCUSSION.—For the present study, a rather flat, marshy area some 125 acres in extent was chosen in a locality of high anopheline breeding known locally as Station 14, North Sauty Creek, Guntersville Reservoir, in northern Alabama. The breeding area was not treated with DDT for the control of larvae for at least two years, but the premises in the vicinity have been routinely treated with a DDT residual spray. The adult collection station associated with the area (#14, Guntersville Reservoir) has continually yielded high counts during the years the reservoir has been impounded, and therefore it was hoped that any reduction in population would be reflected in the station count as compared to over-all averages for the reservoir, both for the present season and for previous seasons. The treatment was applied during the first week in April by airplane. The material used was a 20 per cent solution of DDT[1] and was sprayed from the plane at the rate of 1.4 pounds of DDT per acre. The height of flight was about 25 feet. The plot was flagged to insure that the required 30-foot swaths would be flown by the pilot. It was impossible to treat all areas which would contribute to the population of the collecting station, but it is believed that the major portion of the area received treatment. No significant kill of fish resulted from this heavy treatment. Immediately following treatment, soil samples were brought into the laboratory, covered with water, and insectary-reared *A. quadrimaculatus* larvae introduced. Inconclusive results were obtained by this method.

Subsequently, insectary-reared larvae were placed in cylinders from quart ice cream cartons located at various points throughout the flooded treatment area. Initially, both first and late third to early fourth instar larvae were used, but later only the larger ones were employed due

[1] In *Velsicol NR-70* (w/w).

to the difficulty involved in handling the smaller larvae. The containers were examined after about 24 hours for mortality. The mortalities obtained from larvae introduced into the treatment area showed that a high level of insecticidal activity was maintained for at least 3 weeks, but that larvae in an advanced stage of growth were only slightly affected 4.5 days following treatment.

Collections of adults from Station 14, an unsprayed barn housing stock, located about one-quarter of a mile west of the treatment area, were begun 23 days following treatment. Weekly adult female *Anopheles quadrimaculatus* collection records for Station 14 and Guntersville Reservoir were averaged for the 5-year period, 1944 through 1948, with the data on the 1949 season being presented as a per cent of the 5-year average in figure 1.

Dipping to determine the natural larval population was begun the third week following treatment. Five square feet of breeding surface were dipped in the vicinity of each sampling station using the square foot dipper described by Hess (1941). Sampling of the natural population indicated that larval development was retarded for a period of about 7 weeks, and that the adult population did not begin to increase until about the ninth week following treatment as shown in figure 1. It is difficult to make an absolute comparison between the adult collection data for the 1949 season and those for the five previous seasons due to differences in weather and initiation and intensity of breeding. These data suggest, however, that the pre-flooding treatment retarded the development of the initial peak adult population for a period of about 5 weeks.

SUMMARY.—A barrier strip was treated with a residual spray at a rate of approximately 280 mg. DDT per square foot. Of 5000 dyed adults of *Anopheles quadrimaculatus* released within the barrier, only 0.12 per cent were recovered over a period of 8 weeks following treatment. The results suggest that the barrier was highly effective in controlling *A. quadrimaculatus*.

A preflood application of DDT at the rate of 1.4 pounds per acre appeared to retard the development of larvae for about seven weeks and to delay the build-up of the adult population for about eight weeks. Larvae introduced into the treatment area were significantly affected for at least three weeks.[1]

[1] *Acknowledgments.* The author wishes to acknowledge the invaluable assistance of Dr. W. E. Snow who planned, and with the aid of John Pitchford, did much of the mosquito collecting in connection with the barrier strip experiment. The assistance and advice of R. E. Sparkman greatly facilitated the completion of the spray operations. Thanks are due also to W. O. McGee and all other members of the Biology Section for their aid during the course of these experiments. Acknowledgment is also made of the guidance and help given by Dr. T. F. Hall during the course of these experiments.

LITERATURE CITED

Anonymous. 1948. Recommendations for the preparation and use of a DDT adhesive spray for outside use. U. S. Pub. Health Ser., Communicable Disease Center, Tech. Devel. Div., Savannah, Ga., Dec. 31.

Goodwin, M. H., Jr. 1949. Observations on dispersal of *Anopheles quadrimaculatus* Say from a breeding area. Jour. Nat. Mal. Soc. **8**(3): 192–7.

Hess, A. D. 1941. New limnological sampling equipment. Limnological Soc. Amer. Spec. Pub. 6.

Horsfall, W. R. 1946. DDT used to control a rice-field mosquito, *Psorophora confinnis*. JOUR. ECON ENT. **39**(6): 723–5.

Madden, A. H., A. W. Lindquist, and E. F. Knipling. 1945. DDT residues on vegetation and ground litter to control adult salt-marsh mosquitoes. Mosquito News. **5**(3): 100–4.

Madden, A. H., H. O. Schroeder, and A. W. Lindquist. 1947. Residual spray applications to salt-marsh and jungle vegetation for control of mosquitoes. JOUR. ECON. ENT. **40**(1): 119–23.

McDuffie, W. C., J. F. Sharp, H. F. Cross, C. R. Twinn, and W. M. Wilson. 1949. The effectiveness of prehatching treatments for the control of Arctic mosquitoes. Mosquito News. **9**(2): 51–6.

Rees, B. E., T. G. Raley, and E. D. Davis. 1949. Pre-hatching treatment of irrigated lands with DDT, dichlorodiphenyl dichloroethane, and gamma-benzene hexachloride for control of floodwater mosquitoes. JOUR. ECON. ENT. **42**(4): 586–90.

Snow, W. E. 1949. Studies on portable resting stations for *Anopheles quadrimaculatus* in the Tennessee Valley. Jour. Nat. Mal. Soc. **8**(4): 336–43.

Stanley, W. W. 1945. Leaf area and its relation to application of insecticides. JOUR. ECON. ENT. **38**(6): 703–5.

Wisecup, C. B., and C. C. Deonier. 1945. DDT for the control of *Psorophora* mosquitoes. JOUR. ECON. ENT. **38**(2): 250–2.

Field Studies with Insecticides to Control the Lone Star Tick in Texas[1]

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The lone star tick, *Amblyomma americanum* (L.), is an important pest of man and animals in southwestern Texas. It is injurious to livestock, causing loss of weight, and is a predisposing factor in infestations of the screw-worm, *Callitroga americana* (C. & P.). In recent years this tick has become more prominent because of its association with the transmission of Rocky Mountain spotted fever, American Q fever, Bullis fever, and possibly tularemia (Cooley & Kohls 1944, Brennan 1945). Bullis fever was first recognized in 1942, when about 600 cases occurred among the personnel of one division training at Camp Bullis, and this outbreak was largely responsible for the abandonment of the camp as a maneuver area.

With the end of the war and the subsequent release of temporary training camps, the Army again became interested in utilizing the permanent reservation at Camp Bullis as a troop-training center and requested the Bureau of Entomology and Plant Quarantine to study the possibility of alleviating the tick menace. Studies on area control with various insecticides were therefore started early in 1946 and continued throughout the active tick season. Additional studies were made in 1947 at Camp Bullis, and in 1948 at Kerrville, Texas, where conditions were almost identical to those at Camp Bullis. The results obtained from these 3 years of field tests are given in this paper.

ABUNDANCE AND ACTIVITY OF TICKS AT CAMP BULLIS.—A survey of the Camp Bullis Reservation early in May 1946 revealed a heavy, general infestation of the lone star tick. It was apparent that conditions were exceptionally favorable for both survival and multiplication of this species. First, the land was totally uncultivated and ungrazed, and otherwise unaffected by ordinary ranch practices. Second, plenty of deer, the favored host, and many suitable small animal and avian hosts insured a continuous and maximum production of ticks each year. Third, the abundance of thick, wooded areas, composed largely of oaks and cedars, provided an unlimited amount of cover in the form of ground litter. The greatest number of ticks occurred in such areas, but light infestations also existed in open, grassy areas.

Lone star ticks are fairly numerous and active on warm days during late January and early February. They become increasingly abundant and active as the spring season advances. Nymphs and adults occur in the greatest numbers during late May and early June. Little or no tick activity is apparent during the late fall and early winter months. Larvae appear late in May and attain a peak of abundance early in July. Larvae, however, continue to exist in moderate numbers through August and September.

From this brief résumé of its seasonal history, it is apparent that the lone star tick is active in abundance over a very long period and, as it attacks such a wide variety of animal and avian hosts, its control is a very difficult problem.

METHODS AND MATERIALS.—Smith & Gouck (1944, 1946) found DDT, nicotine sulfate, and pyrethrum to be effective against the lone star and other species of ticks that infest houses, yards, and camp sites. Of these materials only DDT provided effective control for any length of time. Since conditions at Camp Bullis were so different from those under which Smith & Gouck's studies were made, tests were repeated with these insecticides at various strengths and dosages, both in sprays and dusts. Tests were also made with chlordane, toxaphene, and technical benzene hexachloride (labeled as containing 18 per cent gamma isomer) as dusts and sprays, and with *Lethane 380* (organic thiocyanates) and *Thanite* (mainly isobornyl thiocyanoacetate) as sprays. In 1948 additional studies were made at Kerrville, Texas, with DDT, chlordane, toxaphene, benzene hexachloride (10 per

[1] This work was conducted under funds allotted by the National Military Establishment to the Bureau of Entomology and Plant Quarantine, and some of the data were presented before a meeting of the Texas Entomological Society, San Antonio, Tex., March 1947.

[2] The following persons assisted in conducting the tests reported herein: In 1946, Carroll N. Smith, F. S. Faulkner, and C. L. Smith; in 1947, E. E. Vallier and T. McGregor; and in 1948, H. Leighton and E. E. Vallier.

cent gamma isomer), and parathion as dusts.

The test areas ranged in size from about 1000 square feet to several acres. In tests on 0.5 acre or less the dusts were applied with a rotary hand duster, and the sprays with a 3-gallon knapsack pressure sprayer. On large plots dual-purpose power equipment was used. In 1947 one area of more than 200 acres was treated with several power dusters to determine the feasibility and effectiveness of large-area treatments. In 1946 DDT solutions were sprayed from an airplane (N3N3) to determine the practicability of this means of dispersal for controlling ticks over large areas. The plane was equipped with underwing spray booms which delivered 16 gallons per minute. Each plot was sprayed from one to four times in narrow swaths to apply the desired dosages.

Estimates of the tick populations were obtained before and at intervals after treatment by dragging a flannel flag (3 by 5 feet) over an established course. Spot counts were also made by spreading the flag on the ground at a set point for 2 to 4 minutes and counting the ticks as they were removed from the flag. The ticks were then returned as nearly as possible to their original location. This dual-count system was found to provide a more accurate estimate of the population day after day than either method alone.

RESULTS: *Tests with ground sprays.*—A large series of tests was conducted with DDT oil solutions, emulsions, and suspensions applied with ground equipment. Preliminary tests were made with dosages of 0.5 to 2.0 pounds of DDT per acre applied in 5 to 20 gallons of oil or water carrier. The immediate control with these small volumes of liquid carrier was extremely poor, but in some tests fair to good control was obtained within 2 to 4 weeks. The results from these tests were generally unsatisfactory, however, pre-

Table 1.—Results of tests with several insecticides applied as sprays to small plots to control the lone star tick, Camp Bullis, Tex., 1946.

Dosage per Acre		Original Number of Ticks[1]	Per Cent Reduction of Ticks in—								
Toxicant (Pounds)	Water (Gallons)		48 Hours	1 Week	2 Weeks	4 Weeks	6 Weeks	10 Weeks	14 Weeks	18 Weeks	Average for 1 to 6 Weeks
50% DDT wettable powder											
1	50	124	22	83	87	97	97	94[2]	94	55	91
2	50	283	62	89	99	99	86[2]	93	56	—	93
25% DDT emulsion concentrate											
1	50	89	58	65	57	92[2]	87	92	84	91	75
	100	161	93	98	88	93	96	91[2]	88	—	94
2	50	157	73	90	90	93	90	94[2]	97	88	91
	100	101	91	92	96	92	99	89[2]	94	—	95
	25[3]	229	94	97	99	99	93	89[2]	77	—	97
4	25[3]	284	99	99	99	100	99	95	77	—	99
32% Benzene hexachloride (18% gamma) wettable powder											
0.5	50	192	94	95	87	85[2]	86	89	91	83	88
1	50	102	95	94	66	69	77[2]	86	89	78	77
10% Benzene hexachloride (18% gamma) emulsion concentrate											
1	50	178	99	95	75	59	49[2]	4	40	39	70
2	50	69	94	74	78[2]	90	99	84	—	—	85
25% chlordane emulsion concentrate											
1	50	170	84	92	98	92	98	98	—	—	95
2	50	94	91	97	93	73	80	84	—	—	86
25% Toxaphene emulsion concentrate											
1	50	96	64	88	97	95[2]	95	93	—	—	94
2	50	169	92	92	92	88	83	81	—	—	89

[1] Counts include only nymphs and adults, and reductions are based only on these stages.
[2] Larvae present for first time, also noted subsequently, and apparently were not affected by residue of treatment.
[3] Applied with fine-mist nozzle, others applied with coarse-spray nozzle.

sumably because of inadequate coverage and penetration of the tick-infested ground litter. In subsequent tests, therefore, 50 to 100 gallons of liquid carrier were used. The results from most of these tests, all with wettable powders and emulsion concentrates, are summarized in table 1.

In general, 1 to 2 pounds of DDT per acre provided good to excellent control of ticks within 2 to 14 days and established a residue which apparently prevented reinfestation for 4 to 6 weeks, or more. The 2-pound dosage provided somewhat better immediate control than the 1-pound dosage, but there was little difference in residual effectiveness. The use of 100 gallons of water per acre to apply these dosages increased the immediate effectiveness but did not extend the residual effectiveness beyond that shown by the same dosages applied with 50 gallons of water. In two additional tests equally good coverage and control were obtained with only 25 gallons per acre applied as fine-mist sprays, the time required for spraying being approximately the same as for 50 gallons applied as coarse sprays.

Chlordane and toxaphene at 1 and 2 pounds per acre in emulsions gave control of ticks comparable to these dosages of DDT. The 2-pound dosage of each insecticide gave higher immediate reductions than the 1-pound dosage but provided no greater residual effectiveness. In fact, the best average reduction over a 10-week period occurred in plots treated with the lower dosage.

In comparative tests technical benzene hexachloride (18 per cent gamma isomer) demonstrated a superiority over DDT and the other insecticides as a knock-down agent, but was less effective in residual toxicity. In all the spray tests the number of ticks was reduced 94 to 99 per cent at the 48-hour counts. Many of the ticks apparently recovered, however, presumably from the fumigatory effects and not from actual contact, as the reduction dropped to 66 to 87 per cent within 2 weeks, and in most tests remained thereafter at about this level.

In other tests, not shown in the table, 50 to 100 gallons per acre of 0.5 and 1 per cent solutions of nicotine in water provided excellent immediate immobilization of ticks, but a sizable portion of the population recovered within 24 hours. Two per cent emulsions of *Lethane 380* and *Thanite* applied at 50 gallons per acre proved relatively ineffective both for knock-down and control of ticks.

The spray tests showed the importance of thoroughly wetting the surface of the tick-infested litter at close range. Attempts at coverage by drifting spray with either hand or power equipment proved generally unsatisfactory, especially for immediate reduction of tick populations.

Tests with airplane sprays.—Six tests were conducted in which 2.5 to 5 pounds of DDT in 1.5 to 12 gallons of liquid per acre were applied by plane from tree-top height. One test was made with benzene hexachloride applied at 1.5 pounds per acre. The results of these tests are given in table 2.

Treatments of 2.5 and 5 pounds of DDT per acre in 1.5 to 3 gallons of oil

Table 2.—Results of airplane spraying tests with DDT and benzene hexachloride against the lone star tick. (Applications made between May 21 and May 30, 1946.)

Material	Dosage per Acre		Original Number of Ticks[1]	Per Cent Reduction of Ticks in—						
	Toxicant (Pounds)	Liquid (Gallons)		48 Hours	1 Week	2 Weeks	4 Weeks	6 Weeks	10 Weeks	Average for 1 to 6 Weeks
DDT:										
20% in Velsicol NR-70[2]	2.5	1.5	262	0	0	16	39	44	—	25
	5	3	395	0	0	4	0	—	—	1
10% in water emulsion	2.5	3	342	20	0	0	24	—	—	8
10% in Velsicol NR-70-lubricating oil (50–50)	5	6	467	9	65	50	71	69	92	64
10% in cyclohexanone-lubricating oil (1–3)	5	9	308	27	64	59	80	76	78	69
5% in water emulsion	5	12	473	0	21	60	77	71	88	57
Benzene hexachloride (18% gamma isomer) 5% in water emulsion	1.5	3	761	45	21	37	55	69	—	46
Untreated Checks[3]	—	—	894	—	11	55	47	65	89	45

[1] Only nymphs and adults present when sprayed. Larvae appeared in all plots 2 to 4 weeks after spraying, but are not included in calculations of control.
[2] Chiefly tetramethylnaphthalene.
[3] Counts for 3 check plots combined to show trend of tick abundance.

were relatively ineffective in reducing tick populations. Somewhat better results were indicated from a 5-pound dosage applied in 6 to 12 gallons of oil or emulsion, but even these heavy treatments failed to provide satisfactory control. Technical benzene hexachloride (18 per cent gamma isomer) at 1.5 pounds per acre also gave poor control. In most of these tests the reduction of ticks after the second week did not differ greatly from the natural reduction in the untreated check areas.

Observations made during the aerial spraying indicated that most of the spray impinged on the overhead and ground vegetation. Apparently insufficient material actually reached the ground to establish an effective surface residue or penetrate the tick-infested litter. From the poor results obtained, it appeared that aerial sprays would be neither effective nor practical for the control of ticks under conditions at Camp Bullis. Better results may be possible with this method under other conditions and against other species of ticks.

Tests with dusts.—The accuracy and carefulness necessary in the application and the almost prohibitive quantities of liquid required to insure good control with sprays suggested that dusts might be a more practical means of applying tick-killing insecticides over large areas. Tests were therefore conducted with DDT, chlordane, toxaphene, and benzene hexachloride (18 per cent gamma isomer); in concentrations of 2.5 to 10 per cent in pyrophyllite applied at rates of 10 to 40 pounds of dust per acre. The results of most of these tests are summarized in table 3.

In contrast to sprays, DDT dusts at dosages of 1 and 2 pounds of toxicant per acre proved inadequate for effective control of ticks, except late in the season when the population consisted almost entirely of unfed nymphs. Early in the season, when adult ticks were abundant, 40 pounds per acre of 10 per cent DDT dust was required for control. Even this heavy application showed variable immediate and residual effectiveness, but satisfactory control was indicated in four

Table 3.—Results with several insecticides applied as dusts to small plots to control the lone star tick, Camp Bullis, Tex., 1946–1947.

Dosage per Acre		Original Count of Ticks[1]	Per Cent Reduction of Ticks in—						
Toxicant (Pounds)	Total Dust		48 Hours	1 Week	2 Weeks	4 Weeks	6 Weeks	10 Weeks	Average for 1 to 6 weeks
				DDT					
1	40[3]	242	53	59	68	70	81	—	70
		98	34	60	73	—	—	—	—
	20	422	0	0[2]	15	0	—	—	—
2	40	184	57	67[2]	77	80	79	—	76
	20	254	58	71[2]	67	79	55	81	—
4	40	219	90	78	69	72[1]	73	95	68
				Chlordane					
1	40[3]	209	77	75	81	80	88	—	81
		418	61	97	99	—	—	—	—
2	40	200	98	99	99	98	97[1]	—	98
				Toxaphene					
1	40[3]	241	76	82	94	73	73	—	81
		146	70	97	96	—	—	—	—
2	40	237	98	98	98	98	99	—	98
				Benzene hexachloride (18% gamma)					
1	40[3]	249	97	95	89	70	76	—	83
	20	157	81	58[1]	35	42	—	—	—
2	40	470	73	50[1]	48	39	—	—	—
	20	127	95	36[1]	12	38	58	77	36
4	40	333	99	99	95	88[1]	88	89	93

[1] Larvae present. Also noted subsequently.
[2] Average of 1 to 3 replications. Nymphs and adults only.
[3] Tests made in 1947; all others made in 1946.

of five test plots for a period of about 10 weeks. When the results of the unsatisfactory test were averaged with those of the other tests, the control for the 4-pound dosage was only about 73 per cent between the first and sixth weeks after treatment, or about the same as for dosages of 1 and 2 pounds per acre.

Chlordane and toxaphene appeared to be at least equally effective as DDT. When applied as dusts at the rates of 1 and 2 pounds of toxicant per acre, each gave from 75 to 99 per cent reduction of ticks within 1 week. The 2-pound dosages gave much higher immediate control and longer residual effectiveness than 1 pound.

Applications of 1 and 2 pounds of benzene hexachloride (18 per cent gamma isomer) per acre as dusts immobilized most of the ticks within a few hours and seemed to give excellent control within 48 hours. Counts 1 to 2 weeks after treatment, however, showed light to heavy populations of ticks. Most of these individuals apparently had been anesthetized by the vapors of the insecticide or had failed to receive a lethal amount from contact, and therefore recovered within a short time. Prolonged control was obtained only in the plots treated with 4 pounds of benzene hexachloride per acre. At lower dosages this insecticide provided considerably less residual effectiveness than the other materials tested.

In 1946 a series of tests was made to determine whether DDT and benzene hexachloride might be combined to obtain better immediate and lasting control than was indicated for the individual materials. Three dust mixtures were used, as follows: 5 per cent of DDT plus 2.5 per cent of benzene hexachloride; 5 per cent of each, and 7.5 per cent of DDT plus 2.5 per cent of benzene hexachloride (18 per cent gamma). At 20 and 40 pounds per acre the 7.5 per cent DDT-2.5 per cent benzene hexachloride dust was the most effective mixture. It provided almost perfect immediate and continuing control for approximately 6 weeks, compared with about 4 weeks for the other dusts. However, it did not provide any longer residual effectiveness than the same amount of DDT alone.

In additional tests it was found that 2 per cent nicotine dusts at 40 pounds per acre immobilized 98 per cent of large tick populations within 2 hours and showed 74 to 81 per cent control after 2 weeks. Lower concentrations of nicotine were less effective. Similar applications of dusts containing 0.2 to 0.4 per cent of pyrethrins gave 79 to 95 per cent knock-down of ticks within 2 hours and showed 66 to 86 per cent control after 2 weeks. Dusts containing 0.2 per cent of pyrethrins and 2.0 to 2.5 per cent of an activator (piperonyl cyclonene or piperonyl butoxide) were somewhat less effective than dusts of pyrethrins alone, both in knock-down and control.

During July 1947 a large-scale practical control test was made at Camp Bullis in which 240 acres were treated with 10 per cent DDT dust at the rate of 43 pounds per acre. The dust was applied by power dusters in swaths of about 40 feet, and good coverage was obtained throughout the area. Twelve points in the treated area were selected for counts and an equal number in the surrounding untreated areas. The results of these counts are summarized in table 4.

The treatment gave 76 per cent control of ticks within 1 week, and the reduction gradually increased to 97 per cent in 6 weeks. The treated area remained relatively free of ticks, including newly hatched larvae, for the rest of the active tick season, whereas the population in

Table 4.—Control of lone star ticks in a 240-acre area dusted with 10 per cent of DDT in pyrophyllite. Camp Bullis, Tex. (Treated July 16–19, 1946; average of 4.34 pounds of DDT per acre. Reduction of ticks based on counts at 12 locations each in treated and untreated areas.)

Plot	Initial Average Number of Ticks	Per Cent Reduction After—						
		1 Week	2 Weeks	4 Weeks	6 Weeks	36 Weeks	40 Weeks	59 Weeks
Treated	149	56	78	91	93	99	99	81
	(Adjusted av.)[1]	76	87	94	97	98	99	63
Untreated	176	+82	+73	+68	+154	5	+7	49

[1] Adjusted by Abbott's formula for population changes in the control area.

the check areas increased gradually until cool weather set in late in September. Counts made 8 to 9 months after treatment (March and April 1948), when ticks had again become active, showed only about 1 per cent as many ticks in the treated area as in the check areas. Another count after almost 14 months (September 1948) revealed only 30 per cent as many ticks in the treated as in the check areas. These results indicate that the large-area treatment minimized reinfestation for about a year, whereas similar treatments on small areas rarely prevented reinfestation for longer than several months.

In connection with this test the U. S. Fish and Wild Life Service found that the treatment caused a rather high mortality of ground- and bush-feeding birds and insectivorous reptiles for about 1 week (George & Stickel 1949). There was no apparent effect on deer or small mammals in the treated area.

The results of further studies at Kerrville, Texas, in 1948, with dusts of different insecticides for the area control of the lone star tick, are summarized in table 5. In these tests benzene hexachloride gave as long-lasting control as DDT, chlordane, or toxaphene, whereas at Camp Bullis it was definitely inferior in this respect. All these materials showed somewhat better results at Kerrville than at Camp Bullis and, except for DDT at 2 pounds per acre and chlordane at 1 pound, there was little difference in the immediate control or residual effectiveness for the first 6 weeks with dosages of

Table 5.—Tests with several insecticides applied as dusts to 0.1-acre plots to control the lone star tick, Kerrville, Tex., 1948. (Dusts applied at 40 to 50 pounds per acre(3 replications each treatment; per cent reduction adjusted to compensate for increases or decreases in the untreated controls.)

Insecticide	Pounds per Acre	Number of Ticks before Treatment[1]	Per Cent Reduction After—						
			1–2 Weeks	4 Weeks	6 Weeks	10 Weeks	12 Weeks	16 Weeks	Average for 6 Weeks
			First series						
DDT	1	321	92	96	94	94	83	23	94
	2	223	79	96	87	0	0	0	85
	4	217	98	96	95	92	67	0	97
Benzene hexachloride (10% gamma isomer)	1	245	98	93	86	87	61	20	94
	2	309	99	97	96	93	92	29	98
	4	449	99	99	98	99	98	80	99
Toxaphene	1	297	98	97	93	80	80	63	97
	2	140	92	98	90	94	88	0	93
	4	216	99	98	99	97	92	0	99
Chlordane	1	190	81	77	73	63	61	0	78
	2	316	90	91	94	93	75	0	91
	4	355	99	97	98	97	95	0	98
Parathion	0.05	176	89	68	69	74	48	—	79
	.25	489	99	98	98	99	94	78	99
	.5	472	99	98	97	97	96	65	98
	1	717	99	99	99	99	98	71	99
Checks:									
First replication[2]	—	206	16	35	33	—	65	70	25
Second replication	—	135	+47	32	16	41	52	61	+12
Third replication	—	147	11	23	22	53	71	—	17
			Second series						
Parathion[2]	0.02	157	81	82	65	0	—	—	77
	.04	171	96	90	67	53	—	—	87
	.08	280	95	96	76	61	—	—	91
	.2	207	96	97	86	0	—	—	94
Check	—	92	41	13	47	52	—	—	36

[1] Both adults and nymphs.
[2] Averages for 2 plots.

1, 2, and 4 pounds per acre. At subsequent observations, however, the 4-pound treatments of each material usually showed better control than the lower dosages.

Parathion at dosages of 0.25 to 1 pound per acre gave control at least equal to that given by the other materials at 1 to 4 pounds per acre. Applications of 0.02 to 0.08 pound per acre gave good to excellent immediate control, but the duration of effectiveness was much shorter than for the higher dosages.

SUMMARY.—The effectiveness of several insecticides for the area control of the lone star tick, *Amblyomma americanum* (L.), was investigated at Camp Bullis, Texas, during the seasons of 1946 and 1947, and at Kerrville, Texas, in 1948.

At Camp Bullis DDT sprays applied at 1 and 2 pounds per acre provided good control within 2 to 14 days and remained effective for 4 to 6 weeks or more. Chlordane and toxaphene applied as sprays at 1 and 2 pounds per acre gave control about equal to that given by similar dosages of DDT. Applications of 0.5 and 1 pound of technical benzene hexachloride (18 per cent gamma isomer) immobilized ticks within a few hours but gave less effective control than the other insecticides. Sprays containing 0.5 and 1 per cent of nicotine sulfate caused immediate immobilization of ticks but the majority recovered within 24 hours. Two per cent solutions of *Lethane 380* (organic thiocyanates) and *Thanite* (mainly isobornyl thiocyanoacetate) were relatively ineffective both for knock-down and kill under the conditions tested. Effective control with sprays appeared to be dependent upon thorough coverage and penetration of tick-infested ground litter, either by the use of large volumes of liquid applied as coarse sprays or of smaller quantities applied as fine-mist sprays from close range. Drifted sprays proved unsatisfactory.

Airplane applications of DDT in oil solutions or in water emulsions at rates of 2.5 to 5 pounds per acre failed to give satisfactory control. Benzene hexachloride applied at 1.5 pounds per acre was also ineffective. It appeared that the aerial applications did not provide a sufficient surface residue or penetrate the ground litter sufficiently to produce a high mortality of the ticks.

Dusts applied at rates of 2 and 4 pounds of DDT per acre gave good control of ticks in some tests, but the results were not consistent. One-pound applications were ineffective. Chlordane and toxaphene at dosages of 1 and 2 pounds per acre appeared to be slightly more effective than DDT at similar dosages. Dust treatments of benzene hexachloride immobilized ticks within a few hours, but only maximum applications of 4 pounds per acre provided satisfactory control for any length of time. Dusts containing both DDT and benzene hexachloride were found to be advantageous for immediate control, but did not provide any longer residual effectiveness than 4-pound applications of the individual chemicals. Dusts containing 2 per cent of nicotine gave excellent immediate knock-down of ticks and good control for about 2 weeks. Lower concentrations were much less effective. Pyrethrum dusts containing 0.2 and 0.4 per cent of pyrethrins gave good knock-down of ticks within a few hours but only 66 to 86 per cent control. The inclusion of 2.5 per cent of piperonyl cyclonene or piperonyl butoxide did not increase the effectiveness of the pyrethrum dusts.

In tests with dusts at Kerrville, Texas, in 1948, benzene hexachloride gave about as long-lasting control at 1 and 2 pounds per acre as at 4 pounds, and was as effective as chlordane or toxaphene, and at least as effective as DDT at each of the test dosages. The results with the different materials were somewhat better at Kerrville than at Camp Bullis, especially so with benzene hexachloride. Parathion at 0.25 to 1 pound per acre gave control at least equal to the other materials at 1 to 4 pounds per acre.

In a large-scale test on 240 acres at Camp Bullis in 1947, 43 pounds of 10 per cent DDT dust per acre gave a 76 per cent reduction of the tick population within 1 week and 97 per cent within 6 weeks. The area remained relatively free of ticks during the remainder of the season, and in April 1948, 9 months after treatment, a control of 99 per cent was indicated. By September 1948, 14 months after treatment, the area contained only 30 per cent as many ticks as the check area. These results indicated that large treated areas may become reinfested much more slowly than small experimental plots of an acre or less.

LITERATURE CITED

Brennan, J. M. 1945. Field investigations pertinent to Bullis fever. The lone star tick, *Amblyomma americanum*. Notes and observations from Camp Bullis, Tex. Tex. Rpts. Biol. Med. **3**: 204–26.

Cooley, R. A., and G. M. Kohls. 1944. The genus *Amblyomma* (Ixodidae) in the United States. Jour. Parasitol. **30**: 77–111.

George, J. L., and W. H. Stickel. 1949. Wildlife effects of DDT dust use for tick control on a Texas prairie. Amer. Midland Nat. **42**: 228–37.

Smith, C. N., and H. K. Gouck. 1944. Sprays for the control of ticks about houses or camps. JOUR. ECON. ENT. **37**: 85–7.

Smith, C. N., and H. K. Gouck. 1946. DDT to control ticks on vegetation. JOUR. ECON. ENT. **38**: 553–5.

DDT-Resistant House Flies and Mosquitoes[1,2]

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A review of available information on the development of insecticide-resistant house flies, *Musca domestica* L., and a summary of the work done at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine were presented at the 1948 meeting of this Association (King & Gahan 1949). Babers (1949) has prepared a more comprehensive review of the general subject of insect resistance to insecticides. The house fly studies were continued during 1949, particularly on methods of control with insecticides other than DDT. In the same year it was discovered that increased resistance of salt-marsh mosquitoes to DDT, comparable with that of house flies, is apparently developing in areas where DDT has been used intensively for several years for mosquito control. The occurrence of resistant strains of *Culex pipiens* L. in Italy has previously been recorded (Mosna 1947, 1948). An unpublished report of the failure of DDT to control the larvae of *Culex* and freshwater species of *Aëdes* in Kern County, Calif., has also been brought to the writer's attention recently. This development in the Culicidae bids fair to repeat the history of house flies and to equal that problem in importance.

CONTROL OF DDT-RESISTANT HOUSE FLIES.—During the spring and summmr of 1949 tests were conducted in two localities in Florida (Dade and Orange Counties) to obtain information on the relative effectiveness of different insecticides applied as residual treatments in dairy barns for the control of DDT-resistant flies. Of these materials, chlordane emulsion at dosages of 100 and 200 mg. of toxicant per square foot was the most consistently effective. In seven treatments the average fly reduction in the 5th week was 94 per cent, ranging from 84 to 99 per cent. Six of these treatments were at 100 mg. and gave better than 85 per cent control for 6 to 11 weeks. In one treatment with a mixture of DDT and chlordane (120 and 90 mg., respectively, per square foot), the degree of control appeared to be about equal to that obtained with chlordane alone.

Lindane wettable-powder sprays at 50 mg. of toxicant per square foot were highly effective for 5 to 9 weeks in three of four tests, but failed after the second week at one location where fly breeding was extremely heavy. At a 25-mg. dosage this material gave good control (85 per cent or better) for 3 to 9 weeks in four tests, but did not remain effective after the first week in four other tests in two barns. In one of these barns three consecutive treatments were ineffective, whereas in the other barn good control for about 9 weeks followed the second treatment. Two treatments at dosages of only 10 mg. were highly effective for 2 to 3 weeks. These applications were made rather late in the summer, when reinfestation pressure was reduced.

With emulsions of dieldrin very good results were obtained for 6 to 10 weeks from five treatments at 50 mg., two at 25 mg., and one at 10 mg. per square foot. One other treatment with an emulsion that broke badly was a failure. In several

[1] This work was conducted under funds allotted by the National Military Establishment to the Bureau of Entomology and Plant Quarantine. Paper presented before meeting of American Association of Economic Entomologists, Tampa, Fla., December 1949.

[2] The details of these studies will be presented in the following articles now in press: Control of House Flies in Barns with Different Insecticides, by I. H. Gilbert, H. G. Wilson, and J. M. Coarsey; Aerial Spray Tests on Adult Salt-Marsh Mosquitoes Resistant to DDT, by C. C. Deonier, T. L. Cain, Jr., and W. C. McDuffie; and Resistance of Salt-Marsh Mosquitoes to DDT and Other Insecticides, by C. C. Deonier, and I. H. Gilbert.

instances the control was rather low during the first 2 weeks, but showed an increase afterwards.

DDT gave good control for several weeks in only one of three tests, and methoxychlor in only one of five tests, both materials being applied at the rate of 200 mg. per square foot. A mixture of the two (100 mg. of each per square foot) gave good results in two tests and very poor results in two others. Toxaphene emulsion at 200 mg. of toxicant per square foot gave very good control for 6 and 8 weeks after two treatments of a new barn, whereas treatments with wettable-powder sprays (three at 200 mg. and two at 100 mg.) were comparatively ineffective. Four tests with a combination of pyrethrum extract and piperonyl butoxide were virtual failures. Two of the treatments were at the rate of 5 mg. of pyrethrins per square foot and two at 10 mg., with 10 times as much piperonyl butoxide in each case. One of each of the concentrates was applied as an emulsion and one of each as a wettable-powder spray.

The provisional conclusions to be drawn from these tests are that chlordane at 100 mg. per square foot and dieldrin or lindane at 50 mg. are effective substitutes for DDT under the conditions represented in these studies. Further tests with dieldrin or lindane at 10 and 25 mg. and of toxaphene emulsions at 200 mg. are needed to determine how consistent the results are under a variety of conditions.

Toward the end of the summer, at the suggestion of E. F. Knipling, tests were started in which low dosages of the compounds were dispersed as space sprays in infested barns several times per week. The preliminary results were promising and the tests should be continued another season.

SUSCEPTIBILITY OF FLIES.—In connection with the above studies, laboratory tests were run to obtain information on the relative susceptibility to DDT and other materials of flies in different barns in the Orlando area. Twenty-one lots of flies from 18 barns were exposed on plywood panels treated with DDT wettable-powder sprays at the rate of 25 mg. of DDT per square foot, and the approximate time required to cause 70 per cent mortality (LT-70) was determined. The average LT-70 was 34.4 minutes for female flies (maximum of 55 minutes) compared with 3.2 minutes for flies from the normal laboratory colony. These records are similar to a smaller series obtained in 1948. For nine lots of flies tested on methoxychlor residues, the average LT-70 was slightly over twice as long as that shown in concurrent tests with the laboratory colony, whereas for lindane, toxaphene, and dieldrin, in a smaller number of tests, the LT-70's were less than twice as long.

LOSS OF RESISTANCE.—Of living fly material received from different localities in the United States in 1948, 14 lots were reared through two or more generations in the laboratory and tested at intervals for susceptibility to DDT residues. All these stocks originally showed some resistance to this insecticide, the LT-70 in the first tests ranging from 4 to 38 times that of the normal laboratory colony. In tests with subsequent generations, there was a great deal of variation in their relative susceptibility. Nearly all stocks showed some loss of resistance but the rate of loss was very inconsistent. Most of the colonies were much less resistant in the second generation than in the first, often followed by an increase approximately to the original level in the third reared generation, then declining again subsequently. One stock showed a decline to a normal level of resistance, whereas another showed increasing resistance in the second to fifth generations. Both these stocks were from a colony of flies obtained from a dairy at Laton, Calif., and furnished us by the Stauffer Chemical Co. of Mountain View, Calif.

Results obtained with a special DDT-resistant colony developed at the Orlando laboratory were referred to in a previous review (King & Gahan 1949). During the fifty-third generation of this colony, a subcolony was started, consisting of flies that were no longer subjected to DDT sprays. Laboratory tests with the ninth and fourteenth generations of these flies showed a marked decline in their resistance, the LT-70 of the original colony varying from about 4 to 11 times that of the subcolony in different tests. The results showed at least that a considerable loss of resistance had occurred. On the other hand, March & Metcalf (1949) have reported that a highly resistant stock of flies obtained from a dairy at Bellflower, Calif., showed little

if any loss of resistance after being reared for 15 generations in the laboratory without further exposure to DDT. There would thus appear to be a fundamental difference in the nature of the resistance in these two stocks. Bruce (1949) also reported no significant change in resistance in a highly resistant colony after 17 generations, although considerable loss was noted in another less resistant colony in six generations.

A supply of pupae from the Bellflower colony was kindly furnished the Orlando laboratory by Dr. Metcalf, and the level of resistance of flies subsequently reared at the laboratory (sixth generation) proved to be considerably higher than any of the wild stocks previously tested there. It was somewhat lower, however, than that of the special DDT-resistant colony (sixty-fifth and sixty-sixth generations). Table 1 gives the comparative records (LT-70 and LD-50) obtained with females of the two stocks of flies in residue tests with DDT and several other insecticides, as well as in tests in which solutions of the materials were applied directly to the thorax with micro-loops. The LD-50 figures represent the micrograms per fly required to cause 50 per cent mortality (1 microgram = 0.001 mg.).

In the last column of table 1 are given the comparative dosages required for the normal laboratory colony of flies, and from this it may be noted that the LD-50 of DDT for the special colony was increased about 100 times. The special colony also showed about a sevenfold increase in resistance to methoxychlor and slight increases for the other materials (up to about 2.9 times for 95 per cent gamma benzene hexachloride).

SALT-MARSH MOSQUITOES RESISTANT TO DDT.—During the summer of 1948 and again in 1949, several mosquito control districts in Florida reported difficulty in obtaining effective control of salt-marsh mosquitoes with DDT sprays. In June 1949 members of the Orlando laboratory observed aerial spraying operations in a portion of Brevard County where DDT had been extensively applied during the previous 4 years. They found that the per cent of control was distinctly lower than that obtained in the same and similar localities in previous years, and indicated that some degree of resistance to DDT had been developed in that area. This was soon confirmed by laboratory tests in which larvae and adults of *Aëdes taeniorhynchus* (Wied.) from suspected areas were compared for susceptibility with material from areas that had been treated infrequently or not at all. Specimens of *A. sollicitans* (Walk.) from one of the intensively treated areas were also included in some of the tests. The larvae and adults of both species from treated areas were much less susceptible to DDT treatments than similar

Table 1.—Relative susceptibility of females of two stocks of DDT-resistant house flies to residues and solutions of several insecticides, with comparative dosages for females of the normal Orlando laboratory colony.

MATERIAL	LD-70 IN MINUTES		LD-50 IN MICROGRAMS		
	Orlando Special	Bell-flower	Orlando Special	Bell-flower	Labora-tory
DDT	230	184	12.3	8.3	0.12
Methoxychlor	150	33	2.4	2.7	.34
Benzene hexachloride:					
95% gamma isomer	—	—	.044	.058	.015
12% gamma isomer	56	44	—	—	—
Chlordane	18	11	.20	.11	.062
Dieldrin	—	—	.024	.014	.012
Heptachlor	—	—	.031	.020	.017
Pyrethrins:					
Alone	—	—	.955	.955	.48
Plus piperonyl butoxide (1:10)	—	—	.082	.085	.048

stages of *A. taeniorhynchus* from other areas. This may be illustrated by the following comparison showing the average mortality obtained in space-spray tests with three lots of *A. taeniorhynchus* adults from each type of area and two lots of *A. sollicitans* collected from a treated area (Table 2).

In residue tests on plywood panels treated at the rate of 25 mg. of DDT per square foot, the LT-70 for one lot of *Aëdes taeniorhynchus* from an untreated marsh was 16 minutes compared with 99 minutes for one lot from a treated marsh, 150 minutes for *A. sollicitans* from the same treated marsh, and 4.7 minutes for laboratory-reared *A. aegypti* L.

Larvicidal tests gave results somewhat similar to those obtained with space sprays, although it was difficult to get the larvae to the laboratory in the proper stage (early fourth instar) for testing. The 48-hour mortalities obtained with DDT in acetone-water suspension at a dosage of 0.01 p.p.m. are shown in table 3.

Comparative tests against some of the same lots of larvae were also run with TDE, toxaphene, dieldrin, lindane, chlordane, and parathion. All of these except TDE were about as toxic to larvae from the intensively treated area as to those from other areas. TDE, like DDT, was much less effective against the former. Parathion was by far the most toxic of the materials with an effective dosage of about 0.001 p.p.m.

In space-spray tests adult *Aëdes taeniorhynchus* from the treated area showed a high degree of resistance to DDT and TDE, possibly some to toxaphene, but little or none to other materials. The comparative results obtained in the treated and the untreated areas are summarized in table 4.

FIELD TESTS AGAINST ADULT SALT-MARSH MOSQUITOES.—Airplane spray tests with various materials as adulticides were undertaken in the intensively treated portion of Brevard County on plots varying from 160 to 3000 acres. The materials were applied as fuel-oil solutions, with auxiliary solvents when required, and the effects were determined by comparing the average number of mosquitoes alighting on the clothing; counts were taken at a number of places in each plot the day before treatment and at 6 and 24 hours after treatment.

Lindane was the most effective material, and at a dosage of 0.1 pound per acre gave good control of adults both in open marshes where *Aëdes sollicitans* was the principal species and in thick woods where *A. taeniorhynchus* predominated. Good control on four open-marsh plots was also obtained at a dosage of 0.05 pound per acre, but one treatment at 0.025 pound was ineffective. Technical benzene hexachloride (12 per cent gamma isomer) at 0.2 and 0.4 pound per acre gave results that compared favorably with lindane at 0.05 and 0.1 pound on the open marshes, but it was somewhat less effective in the woods.

Table 2.—Per cent mortality of mosquito adults in laboratory space-spray tests with DDT.

SPECIES AND TREATMENT	SEX	TREATED AREAS	UNTREATED AREAS
Aëdes taeniorhynchus[1]			
0.5% spray	Males	28	95
	Females	6	68
1.0% spray	Males	56	98
	Females	18	83
Aëdes sollicitans			
Lot 1. 2.0% spray	Both sexes	42	—
Lot 2. 1.0% spray	Males	63	—
	Females	19	—

[1] Averages for 3 lots from each type of area.

Table 3.—Per cent mortality after 48 hours of mosquito larvae in laboratory tests with DDT.

SPECIES	RANGE	AVERAGE
Aëdes taeniorhynchus		
Treated area (3 lots)	0– 44	16
Areas occasionally treated (2 lots)	86– 96	91
Untreated area (4 lots)	58–100	85
Aëdes sollicitans		
Treated area (1 lot)	—	18

Table 4.—Per cent mortality after 24 hours of *Aëdes taeniorhynchus* adults in space-spray tests with different materials (2% concentration except as noted).

CHEMICAL	TREATED AREA (1 LOT)		UNTREATED AREAS (AVERAGE OF 3 LOTS)	
	Male	Female	Male	Female
DDT	67	11	99	97
TDE	13	0	98	87
Toxaphene	83	28	96	75
Lindane:				
1%	100	100	100	100
0.5%	71	76	92	57
Benzene hexachloride, technical	92	75	98	69
Chlordane	95	84	97	70

Dieldrin at a 0.1-pound dosage was about equal to lindane at the same dosage in one series, but in two other series at dosages of 0.1 and 0.05 pound per acre the results were less favorable. Parathion, which was tested only in one series, gave good control of *Aëdes sollicitans* at dosages of 0.1 and 0.05 pound per acre, but was less effective in the woods than in the open marshes.

Chlordane and DDT gave variable results, and neither material was highly effective in most tests at 0.2 and 0.3 pound per acre. This was true also of toxaphene at a 0.2-pound dosage. A 0.6-pound dosage of chlordane showed a high reduction at the 6-hour counts but not at the 24-hour counts.

Of the four best materials, technical benzene hexachloride is the least expensive at present prices, even if used at 5 times the concentration of the others. This material, however, frequently causes burning of the skin or headache in handlers and has a disagreeable odor. It is much less soluble than most of the chlorinated insecticides, so the amount of auxiliary solvent required to obtain a 5 or 10 per cent solution in fuel oil increases materially the cost of spray preparation. Technical products having a gamma content of 35 to 40 per cent are becoming commercially available and require less auxiliary solvent to obtain the required percentage of gamma.

Tests with *Anopheles pseudopunctipennis* Theob.—During the spring of 1948 an experiment was undertaken in Mexico to determine whether this species of mosquito had acquired increased resistance in a village where all the premises had been thoroughly treated with DDT residual sprays each spring, beginning in 1945 (Gahan *et al.* 1949). To obtain sufficient specimens of a known age for testing, eggs were procured from gravid females collected in the village and the larvae were reared to adults. These were exposed for a selected period on DDT-treated panels and were compared with reared adults from a nearby untreated village. The average mortality among specimens from the treated village was actually somewhat higher than that in the control group, the percentages for males and females being 70 and 42 for the former and 54 and 33 for the latter. It appeared, therefore, that no increase in DDT resistance had as yet occurred.

DDT RESISTANCE IN BODY LICE.—In an experiment carried out by G. H. Culpepper and Carroll N. Smith, third-instar nymphs of the body louse, *Pediculus humanus corporis* Deg., were exposed each generation to a concentration of DDT powder sufficient to cause about a 75 per cent mortality. After eight generations this colony failed to show any increase in resistance. In another experiment a lot of about 4000 adults was exposed to a concentration that caused the death of all except 10 individuals, 8 of which were females. The progeny of these lice were reared through six generations (without further exposure to DDT) before sufficient numbers were available for testing. At that time there was no evident increase in resistance.

SUMMARY.—Tests were conducted in dairy barns in two localities in Florida to determine the relative effectiveness of different insecticides applied as residual treatments for the control of DDT-resistant house flies, *Musca domestica* L. Chlordane emulsion at dosages of 100 and 200 mg. of toxicant per square foot was the most consistently effective material, followed in order by dieldrin emulsion at 50, 25, and 10 mg.; lindane wettable-powder spray at 50 mg.; toxaphene emulsion at 200 mg.; and a DDT-methoxychlor wettable-powder spray at 200 mg. (100 mg. of each material). Most of the tests with the last two materials alone were failures, as were also all of four tests with pyrethrum extract. A few preliminary tests with space sprays applied at frequent intervals appeared of promise.

In tests with 21 lots of flies from different barns, exposed to DDT-treated plywood panels, the exposure time required to produce 70 per cent mortality of female flies ranged from about 4 to 17 times (average of 11 times) that of a normal laboratory colony. For nine lots tested on methoxychlor, the LT-70 was slightly over twice as long as that for the laboratory colony, whereas for lindane, toxaphene, and dieldrin, in smaller numbers of tests, the LT-70's were less than twice as long.

Of 14 lots of flies from natural sources which were reared in the laboratory, all showed a great deal of variation in susceptibility to DDT in consecutive gen-

erations, but most of them gave evidence of a definite loss of resistance after a few generations. A highly resistant laboratory colony was much less resistant to several other insecticides. This colony showed a partial loss of resistance to DDT after nine generations without further exposure to the compound.

Evidence was obtained that increased resistance to DDT was developing in salt-marsh mosquitoes, *Aëdes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.), in areas that have been subjected to intensive treatment with this material for several years. In laboratory tests both larvae and adults from such areas were much more difficult to kill with DDT than were similar stages from untreated areas. This was also true for TDE but not for lindane, chlordane, parathion, or dieldrin.

In large-scale field tests, DDT was considerably less effective against adults than it had been in the same locality in previous years. With other materials the best results were obtained with lindane applied at rates of 0.1 and 0.05 pound per acre. Parathion at these dosages and technical benzene hexachloride (12 per cent gamma isomer) at dosages of 0.4 and 0.2 pound gave results comparable with those obtained with lindane in open marshes, but were somewhat less effective in the woods. Chlordane at 0.2 and 0.3 pound and toxaphene at 0.2 pound per acre were not highly effective.

In laboratory tests with adults of *Anopheles pseudopunctipennis* Theob. from a Mexican village where all premises had been treated with DDT residual sprays once each year during the previous 3 years, there was no indication of increased resistance to this material.

Human body lice, *Pediculus humanus corporis* Deg., have not as yet shown increased resistance to DDT after exposure to sublethal dosages.

LITERATURE CITED

Babers, F. H. 1949. Development of insect resistance to insecticides. U. S. Bur. Ent. and Plant Quar. E-776.

Bruce, W. N. 1949. Latest report on fly control. Pests and Their Control **17**(6): 7, 28.

Gahan, J. B., W. G. Downs, and H. Celis. 1949. Control of *Anopheles pseudopunctipennis* in Mexico with DDT residual sprays applied in buildings. Part II. Amer. Jour. Hyg. **49**(3): 285–9.

King, W. V., and J. B. Gahan. 1949. Failure of DDT to control house flies. JOUR. ECON. ENT. **42**(3): 405–9.

March, R. B., and R. L. Metcalf. 1949. Laboratory and field studies of DDT-resistant houseflies in southern California. Calif. Dept. Agr. Bul. **38**(2): 1–8.

Mosna, E. 1947. Su una caratteristica biologica del *Culex pipiens autogenicus* de Latina. Riv. di Parassitol. **8**(2/3): 125–6. (quoted by Babers, 1949.)

Mosna, E. 1948. *Culex pipiens autogenicus* DDT-resistanti e loro controlle con Octa-Klor e Esacloro-cicoesano. Riv. di Parassitol. **9**(1): 19–25.

C. P. LOUNSBURY

Dr. C. P. Lounsbury, 795 Church Street East, Pretoria, South Africa, long a member of the Association, writes that he is still very much interested in economic entomology and tries to be useful in that connection. In 1893 the Department of Agriculture of Cape Colony, South Africa through the Secretary for the Colonies, in London, asked Dr. L. O. Howard to recommend a man capable of organizing and carrying on intelligent work in economic entomology. Dr. Howard selected Dr. Lounsbury, then a graduate student and instructor at the Massachusetts Agricultural College, who was also highly recommended by Prof. Fernald. Dr. Lounsbury Commenced his duties in Cape Town in 1895 and Dr. Howard has stated that his work was excellent from the start. Among other things Dr. Lounsbury was responsible for legislative action that resulted in the development of nursery inspection and restrictions on plant shipments, and that provided large sums for locust destruction. He also investigated the South African disease-carrying ticks. In 1905 Dr. Lounsbury went to Brazil with Claude Fuller to collect natural enemies of the fruit-fly. He was always interested in biological control and made various efforts to introduce parasitic insects.

In 1910 the four colonies, Transval, Natal, Orange River and Cape of Good Hope were united to form the Union of South Africa. The agricultural departments of the colonies were discontinued and a Union Department of Agriculture was established in which Lounsbury was the Chief Entomologist. By the time of his retirement in 1926 or 1927 Dr. Lounsbury had built up a staff of 25 good men who were located at different points.

H.B.W.

Tests for Synergism Between Nicotine and Phthalonitrile and Between Nicotine and 2,3,4,5,6-Pentachloroanisole

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In our search for synergists for nicotine, we subject a mixture of nicotine and the adjunct to a screening test, following methods already described (Swingle 1943, Mayer *et al.*, 1945, 1946). Any compound which stays on the screen is presumed to have possible synergism, and is then included in tests designed to produce data for dosage-mortality curves. The curves are analyzed by the short method of Wadley (1945). Of 200 chemicals examined to date, a number showed possible synergism (Mayer *et al.*, 1949, Table 1). This paper reports the dosage-mortality data for two of them, phthalonitrile and 2,3,4,5,6-pentachloroanisole, and the calculations for synergism.

Phthalonitrile is itself an insecticide (Schecter & Haller, 1940; Swingle 1941, 1944), as is also pentachloroanisole (Carswell 1944). These facts are confirmed in the present study, wherein there was occasion to measure the toxicity of the compounds alone.

Insect and Foliage Tests.—Nicotine sulfate, nicotine bentonite, and cuprous nicotine cyanide (Mayer *et al.*, 1945) were used at concentrations of nicotine ranging from 0.02 to 10 per cent in attapulgite as a dust carrier, the dosages ranging from 0.2 to 10.0 micrograms per square centimeter.

The insects, their stages, and the foliage used were: Third instars of diamondback moth, *Plutella maculipennis* (Curt.), crucifers; fourth instars of the armyworm, *Cirphis unipuncta* (Haw.), corn and barley; third instars of the celery leaf tier, *Phlyctaenia rubigalis* (Guen.), celery and Swiss chard; fourth instars of the California oakworm, *Phryganidia californica* (Pack.), live oak; third instars of the green dock beetle, *Gastrophysa cyanea* (Melsh.), dock; day-old nymphs of the pea aphid, *Macrosiphum pisi* (Kltb.), Windsor bean; adults of a pomace fly, *Drosophila sp.*); and adults of the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouche), citrus leaves. Larvae of the California oakworm and eggs and larvae of the green dock beetle were collected in the field. All other insects were reared in the laboratory.

The materials were tested against the lepidopterous and beetle larvae by infesting dusted foliage in 9-cm. petri dishes. All leaves were dipped in a 0.5 per cent saponin solution before dust was applied so that none of the particles would drop off in manipulation.

Uniform ages of pea aphid nymphs were obtained by infesting a Windsor bean plant with apterous adults and allowing them to reproduce overnight, after which the adults were removed. The following day the nymphs, which were always located on the under sides of the leaves, were treated by inverting the plant and allowing the dust to settle directly on them.

Greenhouse thrips were tested by confining them in inverted shell vials held to a dusted citrus leaf on a board by rubber bands. The stem of the leaf was immersed in a vial of water.

Tests against pomace fly adults were also carried out in shell vials. Filter papers were cut to line the inner walls of the vials, dipped in ethyl alcohol, and dusted while they were still wet. The papers were then placed in the vials, after which a few grains of granulated sugar and the insects were added. Cheesecloth caps were used, and the vials were kept in a desiccator containing a small amount of water.

The armyworm fumigation test was made by placing one-eighth teaspoon of the material between two sheets of filter paper pressed into the lid of a petri dish containing the insects and untreated foliage. The chemicals, if volatile, soon filled the dishes with their vapors.

Final mortality counts were made at the end of 2 days for the pea aphid and at the end of 3 days for all others.

Foliage injury tests were made by spraying mixtures of the materials on five kinds of plants—corn, cucumber, potato, cabbage, and wax bean. Concentrations were (1) 0.1 per cent of nicotine sulfate

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Table 1.—Complete insecticidal data and calculations for group 7 in Table 2 and Figure 1,A.

Adjunct: Phthalonitrile
Insect: Diamondback moth, L-3

Compound of nicotine: Sulfate
Carrier: Attapulgite. Leaves wet with 0.5% saponin before dusting

Mortality Data for Toxicants Singly

Date of Set	Number of Insects	Nicotine	Mortality		Number of Insects	Phthalonitrile	Mortality	
		μg./cm²	*Per Cent*	*Probits*		*μg./cm²*	*Per Cent*	*Probits*
10/28/46	18	3.7	78	5.77	27	4.2	52	5.05
	26	7.6	96	6.75	29	5.7	76	5.71
					28	7.6	82	5.92
11/ 4/46	18	3.4	61	5.28	20	4.2	45	4.87
	20	5.8	90	6.28	23	5.6	56	5.15
	22	7.7	91	6.34	21	7.6	86	6.08

Mortality Data for Toxicants Combined. Wadley Calculation
Nicotine equivalence = 0.68 at LD50[1]

Date of Set	Number of Insects	Mixture		Nicotine Equivalent[2]	Mortality	
		Nicotine	PHTH			
		μg./cm²	*μg./cm²*	*μg./cm²*	*Per Cent*	*Probits*
10/28/46	23	1.08	0.54	1.44	26	4.36
	24	1.44	.72	1.91	42	4.80
	26	2.10	1.05	2.79	81	5.88
11/ 4/46	23	.98	.49	1.30	17	4.05
	22	1.56	.78	2.07	50	5.00
	18	2.04	1.02	2.71	72	5.58

$$\text{Log ratio} = \frac{\log 2.9 - \log 2.02}{0.06} = 2.6$$

[1] Nicotine equivalence at LD50 = $\frac{2.9 \text{ (dosage from curve for nicotine alone at probit 5)}}{4.3 \text{ (dosage from curve for adjunct alone at probit 5)}} = 0.68$.

[2] Nicotine equivalent = nicotine dosage + (0.68 × adjunct dosage).

plus 0.3 per cent of phthalonitrile and (2) 0.1 per cent of nicotine sulfate plus 0.15 per cent of pentachloroanisole. They were sprayed on the first and seventh days of the test. No injury resulted in 14 days.

STATISTICAL METHODS.—To determine synergism by the Wadley method, it is necessary to establish three mortality curves—for nicotine alone, for the adjunct alone, and for the mixture. Each curve was comprised of three to five dosages; about 30 insects were used with each dosage. The term "set" encompasses the three curves established on a given day. In many cases a single set was plotted (Fig. 1, B). When, however, the data for several sets were consistent when plotted, they were used together (Fig. 1, A, C, and D). Plotting can be done on log-probability paper (Wadley 1945), but it is preferable to convert per cent mortality to probits (Bliss 1935) and plot on semi-log paper.

Mere inspection of the charts gives a rough idea of the presence or absence of synergism. The prime consideration, of course, is the displacement of the nicotine equivalent curve to the left of the nicotine curve. An arbitrary system is used to indicate the degree of synergism as determined by inspection. If the two curves coincide, or if the nicotine equivalent curve is to the right, a minus sign is given; if the nicotine equivalent curve is slightly to the left, one plus sign; if definitely to the left, and especially if the curve is steeper than that for nicotine alone, two or three plus signs. Weight is also given to the number of sets of data, their scatter, and their position on the mortality axis. In this system, one plus is not significant; two indicate significant synergism; and three, marked synergism. If the nicotine equivalent curve is to the

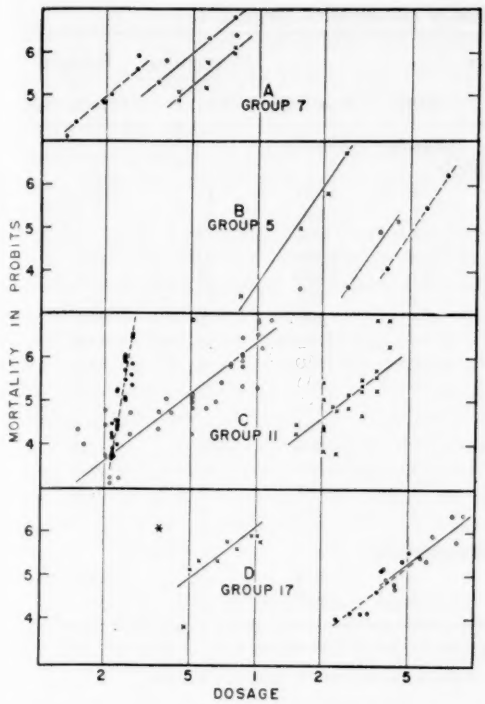

FIG. 1.—Dosage-mortality curves which show the four patterns of synergism of phthalonitrile and pentachloroanisole for nicotine. A, B, and C, phthalonitrile tested on the diamondback moth, greenhouse thrips, and the armyworm, respectively; D, pentachloroanisole tested on the diamondback moth. Open circles indicate nicotine alone, crosses indicate adjunct alone, and broken lines indicate the nicotine equivalent of the mixture. Dosages of toxicants are in micrograms per square centimeter, except in the section of D marked with an asterisk, where they are one-tenth those shown on the abscissa.

right, the same degrees of antagonisms are indicated.

Because of the voluminous data that result from tests of this kind, the data and calculations for only one representative group are presented here (Table 1). Table 2 is a summary of the 18 groups of data.

CALCULATION OF THE MATHEMATICAL VALUE FOR SYNERGISM.—Wadley (1945) states that the interpretation of synergism should be in terms of the standard errors of the observations, but he gives no specific way in which a mathematical value for the degree of synergism can be attained. Finney (1947) proposes such a method, but since his formulas encompass all known factors the calculations are too long and involved for practical application to a long series of data.

Dr. Wadley became interested in our data, and kindly made the Finney calculations not only for four groups of data in table 2 (groups 5, 7, 9 and 15) but for five others obtained under similar test conditions but not included in this paper. He then proposed (1949) the log ratio as a simple short-cut calculation. From the eye-fitted regression lines, the dosages at probit 5 (50 per cent mortality) for nicotine (M_A) and for nicotine equivalent (M_B) are read and converted to logs. Then

$$\log \text{ ratio} = \frac{\log M_B - \log M_A}{0.06}$$

The 0.06 is a generalized error in logs deduced from the nine sets of data. Dr. Wadley is careful to point out that this generalized error holds only for the test conditions used here; it would be modified by use of more insects, more replication, radically different slopes, and other factors.[1]

The calculation of log ratio is given at the bottom of table 1. Table 2 gives the degree of synergism for all groups of data, either calculated by log ratio or determined by inspection when the data were not calculable.

Table 3 gives the results for the nine sets of data by the two methods—the standard Finney "T" and the log ratio. In general the agreement is good. The average value by the Finney method is 3.64, and by log ratio it is 3.44. The agreement of the short-cut method with the standard is satisfactory for the purposes in hand—the handling of a large amount of data to determine whether any apparent synergism is significant, and to obtain a single value for synergism.

In the short-cut calculation, the preliminary procedure is the same as that described by Wadley except for the use of probits. The chart is inspected for synergism with the following guiding principles.

a. If the nicotine and the nicotine equivalent curves obviously overlap, synergism is absent.
b. If the two curves are markedly divergent, synergism (or antagonism) is present, but its extent cannot be calculated by the log-ratio method.
c. If the two curves are separated and are more or less parallel, or can be made so by reasonable adjustment, the degree of significance of the separation can be calculated either by the Finney formulas or by the log ratio formula.

[1] Since the preparation of this manuscript, Wadley has published his procedure. See literature cited, Wadley (1949).

Table 2.—Summary of the evaluation of two nicotine synergists.

Group	Insect	Application[1]	Compound of Nicotine[2]	Sets	Insects	Synergism Pattern (Fig. 1)	Degree of Synergism[3]
				Number	*Number*		
			Phthalonitrile				
1	Pea aphid, 24 hrs. old	D	S	5	1780	C	++
2	Pea aphid, 24 hrs. old	D	B	1	130	C	++
3	Pomace fly, instar A	P	S	4	896	D	−
4	Greenhouse thrips, instar A	D	S	4	1520	D	−
5	Greenhouse thrips, instar A	D	B	1	1329	B	−1.9
6	Diamondback moth, L-3	D	S	1	278	C	+
7	Diamondback moth, L-3	D	S	2	388	A	2.6
8	Diamondback moth, L-3	D	Cu-Cy	6	753	A	1.5
9	Diamondback moth, L-3	D	B	1	210	A	3.4
10	Armyworm, L-4	D	S	8	854	C	++
11	Armyworm, L-4	D	S	9	2817	C	+++
12	Armyworm, L-4	D	S	1	265	C	+++
13	Armyworm, L-4	F	S	1	208	C	++
14	Green dock beetle, L-3	D	S	4	892	C	+
15	California oakworm, L-4	D	S	1	261	A	3.2
16	Celery leaf tier, L-3	D	S	1	212	A	+
			2,3,4,5,6-Pentachloroanisole				
17	Diamondback moth. L-3	D	S	3	661	D	−
18	Armyworm, L-4	D	S	9	3227	D	−

[1] D = dusted leaves; P = vials lined with filter paper impregnated with toxicant; F = fumigating action from isolated toxicant in petri dish.
[2] S = nicotine sulfate; B = nicotine alkaloid on bentonite; Cu-Cy = cuprous nicotine cyanide (Mayer *et al.*, 1945).
[3] See text for explanation.

There are, of course, shortcomings in the short cut. It generalizes all sources of errors, such as the number of insects used at each dosage, the weighting of points in respect of their distance from 50 per cent mortality, the slopes of the regression lines, and natural mortalities, although the latter may easily be included. The log ratio method assumes that these factors are constant. If they change appreciably, the generalized error would have to be recalculated.

The value of the "T" or of the log ratio that is to be deemed significant is open to judgement. A value of 2 is probably significant at the 5 per cent level and 2.6 at 1 per cent; 3 is highly conservative.

The curves for our present data fall into the four synergism patterns shown in figure 1. A is positive, calculable; B is negative, calculable; C is positive, significant, not calculable; D indicates no synergism. Table 2 gives the pattern for each group of data.

CONCLUSIONS.—We conclude that, under the test conditions used, mixtures of phthalonitrile and nicotine sulfate or bentonite showed definite synergism against the pea aphid (groups 1 and 2, table 2), armyworm (10, 11, 12, and 13), California oakworm (15), and diamondback moth (7 and 9); doubtful or no synergism against the green dock beetle (14), celery leaf tier (16), and pomace fly (3); and antagonism against the greenhouse thrips (5). Antagonism may also be construed in the lower portions of those nicotine equivalent curves which cross the nicotine curves (groups 1, 6, and 14 (not shown in figure 1)). It should

Table 3.—Comparison of calculations for synergism by Finney's method and by log ratio. Calculations made by F. M. Wadley.

Data	Finney "T"	Log Ratio
Group 5, greenhouse thrips	−2+	+1.9
Group 7, diamondback moth	3.0	2.6
Group 9, diamondback moth	3.2	3.4
Group 15, California oakworm	3.4	3.2
Bis-(p-chlorophenyl) sulfide, armyworm	4.8	3.1
Bis-(p-chlorophenyl) sulphide diamondback moth	3.3	4.6
Bis-(p-chlorophenyl) sulphide California oakworm	5.6	6.3
Tridecanenitrile, armyworm	−5.2	−2.5
2-Cyclohexylcyclohexylamine, armyworm	−2+	−3.1

be pointed out, however, that in these curves the lower portion involves a higher nicotine-phthalonitrile ratio, and the upper portion a lower ratio. Conceivably there is an optimal range of ratios for effective synergism. Bliss (1939) considers this ratio an important factor in synergism.

Mixtures of nicotine sulfate and pentachloroanisole showed neither synergism nor antagonism against the diamondback moth and the armyworm.

Perhaps the most conspicuous thing in the data is the greatly increased slope of the nicotine equivalent curve in the 8 groups showing pattern C. This might indicate a chemical combination between and phthalonitrile, more probably inside the insect than outside, resulting in a more toxic compound, a phenomenon which Horsfall (1945) called potentiated synergism.

We conclude, in general, that phthalonitrile and nicotine are synergistic against insects (McGovran *et al.*, 1948) but that insect specificity again is in the picture.

SUMMARY.—Under the test conditions used, mixtures of nicotine and phthalonitrile were definitely synergistic against the pea aphid, armyworm, California oakworm, and diamondback moth. They showed doubtful or no synergism against the green dock beetle, celery leaf tier, and pomace fly. They showed antagonism against greenhouse thrips.

Mixtures of nicotine and pentachloroanisole showed neither synergism nor antagonism against the diamondback moth and the armyworm.

In addition to the Finney method for calculating synergism data, a shortcut procedure devised by F. M. Wadley is presented. Each was applied to four groups of present data and to five other groups not included in this paper. The numerical values obtained confirm the conclusions of synergism and antagonism in these cases.

Sprays of the mixtures on five species of plants caused no injury to the foliage.

LITERATURE CITED

Bliss, C. I. 1935. The calculation of the dosage-mortality curve. Ann. Applied Biol. **22:** 134–67.

Bliss, C. I. 1939. The toxicity of poisons applied jointly. Ann. Applied Biol. **26:** 585–615.

Carswell, T. S. 1944. Insecticide suitable for treating green logs and green lumber. U. S. Patent 2,327,338.

Finney, D. J. 1947. Probit analysis. Cambridge Univ. Press. Cambridge, England.

Horsfall, J. B. 1945. Fungicides and their action. Chronica Botanica, p. 160. Waltham, Mass.

Mayer, E. L., J. B. Gahan, and C. R. Smith. 1945. Nicotine insecticides. Part I—New metal nicotine compounds. U. S. Bur. Ent. and Plant Quar. **E-646.**

Mayer, E. L., F. B. Talley, and C. F. Woodward. 1946. Nicotine insecticides. Part II—Search for activators. U. S. Bur. Ent. and Plant Quar. **E-709.**

Mayer, E. L., E. R. McGovran, F. B. Talley, C. R. Smith, D. H. Saunders, and C. F. Woodward. 1949. Nicotine insecticides. Part V. Search for synergists. U. S. Bur. Ent. and Plant Quar. **E-768.**

McGovran, E. R., E. L. Mayer, and F. B. Talley, 1948. Synergistic insecticidal compositions. U. S. Patent 2,449,533.

Schecter, M. S., and H. L. J. Haller. 1940. Insecticide. U. S. Patent 2,200,564.

Swingle, M. C., J. B. Gahan, and A. M. Phillips. 1941. Phthalonitrile as an insecticide. U. S. Bur. Ent. and Plant Quar. **E-548.**

Swingle, M. C. 1948. Exploring the insecticidal possibilities of new materials. In laboratory procedures in studies of the chemical control of insects, edited by F. L. Campbell and F. R. Moulton, Amer. Assoc. Adv. Sci. Pub. **20:** 82–84. Washington, D. C.

Swingle, M. C., A. M. Phillips, and J. B. Gahan. 1944. Preliminary tests of synthetic organic compounds as insecticides. Part I. U. S. Bur. Ent. and Plant Quar. **E-621.**

Wadley, F. M. 1945. The evidence required to show synergistic action of insecticides and a short cut in analysis. U. S. Bur. Ent. and Plant Quar. **ET-223.**

Wadley, F. M. 1949. Short-cut procedure for error estimate in laboratory studies of synergism in insecticides. U. S. Bur. Ent. and Plant Quar. **ET-275.**

The Fermentation of Honey in the Hive

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The fermentation of extracted honey in storage has been a cause of economic losses for many years, Several ideas as to the reason why some honeys ferment and others do not have been advanced by those who have studied the problem.

An old idea, which may still persist in some quarters, is that honey which ferments is "unripe," that is, unsealed at the time of extraction (Root 1918). It is now well known, however, that honey which is apparently normal when extracted from sealed combs may ferment if held in storage for several months.

Fabian & Quinet (1928) found that honey absorbed moisture from a humid atmosphere and gave up moisture to a dry atmosphere. They explained the fermentation of honey in this manner: "... honey being hygroscopic absorbs sufficient water at the surface to lower the concentration of sugars there to a degree compatible with the life of certain yeasts. The yeasts present gradually become accustomed to the higher concentration of sugar and eventually grow throughout the honey." They further stated "In unripe honey, where the bees have been unable to evaporate the water sufficiently, fermentation is most likely to occur."

Dyce (1931) emphasized the relationship of crystallization to the fermentation of honey. He observed that fermentation of market honey generally occurs after crystallization, which results in an increase in the moisture content of the fluid portion of the honey. He rejected the explanation of Fabian & Quinet, since he found that honey which had been hermetically sealed and therefore could not absorb water from the atmosphere fermented after it had crystalized.

Lochhead & McMaster (1931) stressed the importance of the yeast infection as related to the fermentation of honey. They concluded: "The tendency of honey to ferment was found to increase with increasing yeast infection. Although the yeast count tended to increase with increasing moisture content, yet it is not regarded as simply a function of the latter." Lochhead (1933) recognized the importance of the moisture content as related to fermentation and arranged the following table for predicting the probability of fermentation of honey.

Per Cent Moisture	*Effect of Yeast Count Per Gram*
below 17.1	Safe irrespective of yeast count
17.1–18.0	Safe if yeast count does not exceed 1,000
18.1–19.0	Safe if yeast count does not exceed 10
19.1–20.0	Safe if yeast count does not exceed 1
above 20	Always danger of fermentation

(The percentage values were calculated from the old tables, and to convert to values comparable with data presented in this paper (based on Chataway's tables) approximately 1.8 should be substracted from each value).

Stephen (1946) reported a definite relationship between the moisture content of honey and the yeast count. He found that in Canadian honey the yeast count increased about 5-fold for each increase of 1 per cent in moisture content. He also observed that the yeast count and fermentation were influenced by the time honey required for granulation. Honeys with high (over 19 per cent) moisture content were sometimes slow to granulate, hence yeast growth and fermentation were retarded.

All who have studied the problem of honey fermentation are agreed (1) that it is caused by the activity of sugar tolerant-yeasts, (2) that these organisms are commonly found in large or small numbers in all honeys, and (3) that moisture content is an important factor. Other views, which apparently are not well supported, are that honey from certain flowers ferments more readily than others, and that some honeys contain enzyme-like substances which may either favor or inhibit fermentation.

Although a great deal of work has been done on the fermentation of extracted honey in storage, there are few references in the literature to the fermentation of honey in the comb in the beehive. Richter (1912) reported an instance of the spoilage of honey in the hive. The fermentation was so active that the honey flowed down

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over the comb in a frothy stream. Reports by Clark (1942) and Killion (1949) show that Illinois beekeepers may lose money some years because their comb honey contains an excessive amount of water.

Combs of summer honey in the vicinity of Baton Rouge, Louisiana, frequently contain blister-like areas suggestive of a gassy fermentation. These areas vary in size from a single cell with puffed cap to a blister covering about 30 cells. Individual cells, whether capped or still uncapped, often contain many tiny bubbles.

This is a report of laboratory studies made on Louisiana honeys during 1947, 1948 and 1949.

METHODS.—Yeast counts of the honey from the cells in the honey comb were made by both the agar plate method and by the direct microscopic method in 1947, using a hemocytometer. It was impossible to distinguish clearly, by microscopic examination, between yeast cells and other solid particles in the honey so only plate counts were used in 1948 and 1949. For the plate count a medium of the following composition was used: 3 g. beef extract, 5 g. peptone, 15 g. agar, 335 ml. distilled water, and 665 ml. of honey. The honey was added to and mixed with the other ingredients after they had been dissolved by boiling.

For the examination of honey from a single cell, 0.1 ml. pipettes graduated in 0.01 ml. were used. Usually 0.02 or 0.03 ml. of honey constituted a sample. Honey that adhered to the outside of a pipette was removed with a sterile paper towel. The pipette was discharged into a tube of fluid honey agar at a temperature of 42° to 45° C. The agar was drawn into the pipette and discharged three times to remove all of the honey from the inside wall of the pipette. The agar tube was rolled between the hands to distribute the yeast cells and the contents were poured into a sterile petri dish. Incubation was at room temperature (28 to 32° C.) for at least 5 days. Yeast colonies were counted with the aid of a Quebec colony counter unless the colonies were too numerous. In that case a widefield microscope was used.

Moisture determinations were made by means of an Abbe refractometer. Chataway's (1935) conversion table was used to convert the refractometer readings to per cent of moisture.

New combs, drawn out during the honey flow, were used in 1949 so that there would be no possible contamination from old combs. Some new combs were used in 1947.

RESULTS.—The numbers of yeasts in the honey taken from the blisters and from the cells with swollen caps were found to vary between 5 millions and 24 millions per milliliter (Table 1), as determined by the direct count using the hemocytometer. The observations were made with old combs which had been used for several seasons. New combs did not have large blisters, but many cells showed signs of fermentation as indicated by swollen caps. The moisture content of the honey in these cells varied from 17.9 to 21.2 per cent, the direct count of yeasts ranged from 400,000 to 8,000,000, and the plate count varied from 262,000 to 1,600,000 (Table 2). The agreement between the plate count and the microscopic count was not very close. Only the plate count method was employed in subsequent work.

The importance of the methods employed in making the plate count is indicated in table 3. The toxic effect of hypotonic dilution fluids was very marked, and the use of 60 per cent honey as a diluent was less satisfactory than direct plating in honey agar. Potato dextrose agar, commonly used for the enumeration yeasts in food products was unsatisfactory for the examination of honey.

The relationship of moisture content to yeast count and fermentation in individual cells of honey is shown in table 4. In this table the samples have been arranged in the order of increasing moisture content. Those cells which appeared to be normal had relatively low moisture content, and, except for cell No. 5, very low yeast counts. Apparently the critical moisture content for yeast development was about 17.9–18.0 per cent.

Blister-like areas, indicative of active fermentation in the capped cells, have been observed only during the summer honey flow at Baton Rouge. It has not been seen in combs of honey filled during the spring flow. The results of a comparison of the moisture content and the yeast count of freshly capped cells of honey from the spring and summer honey flows in 1949 are given in table 5. New combs were used in each instance. The honey from the spring flow contained less mois-

Table 1.—Yeasts in honey from blistered combs.

Specimen	Size of Blister	Microscopic Count per Ml.
1	20×20 mm.	23,200,000
2	20×25 mm.	21,900,000
3	15×12 mm.	10,100,000
4	single cell, swollen cap	13,100,000
5	single cell, swollen cap	5,800,000
6	single cell, swollen cap	8,800,000
7	single cell, swollen cap	24,000,000
8	15×25 mm.	15,600,000
9	10×10 mm.	5,000,000

Table 2.—The relationship between moisture content, direct count and plate count of yeasts in honey from single cells showing evidence of fermentation.

Honey Cell	Moisture Per Cent	Microscopic Count ×10⁶	Plate Count ×10⁶	Ratio[1] MC/PC
1	17.9	0.4	0.352	1.1
2	17.9	0.5	0.262	1.9
3	18.3	1.7	0.270	6.3
4	19.2	2.2	0.660	3.3
5	19.2	4.5	1.600	2.8
6	19.4	3.0	0.274	10.9
7	19.8	6.5	0.744	8.7
8	20.2	1.0	0.347	2.9
9	20.3	8.0	0.755	10.6
10	20.4	4.1	0.784	5.2
11	21.2	4.2	0.362	11.6

[1] Ratio of microscopic count to plate count.

ture and fewer yeasts than the honey from the summer flow.

Discussion.—There are frequent references in beekeeping literature to "ripe" and "unripe" honey. It is generally believed that when honey is sealed by the bees it is properly ripened. Therefore, sealed honey is assumed to be ripe, while unsealed honey, unless left for extended periods in the hive, is likely to be unripe. There is an old belief that unripe (unsealed?) honey is likely to ferment. Root (1918) said: "There are beekeepers who begin extracting as soon as the bees start sealing over the cells; others count it perfectly safe to extract as soon as the honey is one-fourth to one-half sealed; still others will not extract until the majority of the combs are practically sealed, when none of them are less than three-fourths sealed. . . . It is penny wise and pound foolish to extract honey not thoroughly ripened. . . ."

Our studies of individual cells of sealed

Table 3.—Influence of diluent and plating medium on the yeast count in honey.

Plating Medium	0.01 Ml. Direct[2]	Per Cent Diluting Fluid[1] 0.9 NaCl	10 Honey	30 Honey	60 Honey
Potato dextrose agar	0	0	0	0	3
Potato dextrose agar	lost	0	0	0	2
Count per ml.	500	0	0	0	250
Honey agar	335	0	0	11	214
Honey agar	374	0	0	12	214
Count per ml.	35,400	0	0	1,150	21,400

[1] Ml. of honey to 99 ml. of diluent.
[2] 0.01 ml. added to honey agar at 45° C. and poured into petri dish.

honey indicate that in freshly sealed honey the moisture content varies widely between different cells filled during the same honey flow. It was found that the average moisture content of honey stored during the spring (in the vicinity of Baton Rouge) was less than that stored during the summer time. Sealed honey is not all equally ripe, if the moisture content is used as the criterion. According to Lochhead's prediction table (see above) the honey stored in both the spring and summer honey flows would be likely to ferment because of its high moisture content and the presence of many yeasts.

Table 4.—Relationship of moisture content to yeast count and fermentation in single cells of honey.

Cell	Moisture Per Cent	Appearance of Cap	Yeasts/Ml.
1	16.8	Normal	0
2	17.0	Normal	2,000
3	17.4	Normal	2,500
4	17.6	Normal	4,500
5	17.8	Normal	182,000
6	17.9	Swollen	262,000
7	17.9	Swollen	352,000
8	18.0	Normal	1,250
9	18.3	Swollen	270,000
10	19.2	Swollen	660,000
11	19.4	Swollen	274,000
12	19.4	Swollen	112,000
13	19.7	Swollen	140,000
14	19.8	Swollen	171,000
15	20.2	Swollen	347,000
16	20.2	Swollen	315,000
17	20.3	Swollen	755,000
18	20.4	Swollen	784,000
19	20.8	Swollen	350,000
20	21.2	Swollen	362,000
21	21.2	Swollen	490,000

Table 5.—Seasonal differences in moisture content and yeast count in sealed Louisiana honey in new combs.

CELL	MOISTURE PER CENT	YEASTS/ML.[1]
Honey flow April 26 to May 1, 1949		
1	18.8	166
2	17.2	1,080
3	18.2	0
4	18.2	930
5	18.2	2,140
6	18.0	3,060
7	19.2	32,000
8	17.9	660
Honey flow in latter part of May, 1949		
1	17.9	4,260
2	17.9	265
3	17.4	2,600
4	18.1	7,300
5	17.9	4,800
6	17.0	3,600
7	18.0	1,425
8	17.4	1,330
Honey flow June 20 to July 22, 1949		
1	19.8	520,000
2	19.3	500,000
3	18.8	230,000
4	17.9	230,000
5	18.2	128,000
6	19.0	128,000
7	19.4	138,000
8	19.3	430,000
9	19.6	688,000
10	19.0	287,000
11	19.0	172,000
12	18.7	185,000
13	20.3	1,290,000
14	18.4	172,000

[1] Plate count.

White clover nectar, probably the most important source of the spring honey, has an average sugar concentration of 43 per cent. Peppervine, *Ampelopsis arborea*, and eardrop vine, *Brunnichia cirrhosa*, both sources of summer nectar, have nectar with a lower sugar concentration. The average sugar concentration of peppervine nectar is 26 per cent and of eardrop vine is 27 per cent, (Oertel 1949).

In view of the findings reported here it is not surprising that fermentation of honey in the hive occurs in the Baton Rouge area. The mean temperature of Baton Rouge is 67.9° F. in April and 81.7° F. in July. The relatively high temperature in July, in conjunction with the relatively high atmospheric humidity, probably prevents the bees from removing enough moisture from the honey and thus favors the development of fermentation.

SUMMARY.—The fermentation of honey in the hive has been frequently observed in the vicinity of Baton Rouge, La. Active fermentation, resulting in swollen caps or in some cases the formation of blister-like areas on the comb, was observed only during the summer honey flow. Studies of individual sealed honey cells indicated considerable variation between the moisture content and the yeast counts of different cells filled during the same honey flow. The moisture content and yeast counts were considerably lower in the spring than in the summer honey.

The fermentation of honey in the comb in the colony may be attributed to the high moisture content of the honey when sealed, the high yeast infection, and the high outdoor temperature.

LITERATURE CITED

Chataway, H. D. 1935. Honey tables, showing the relationship between various hydrometer scales and refractive index to moisture content and weight per gallon of honey. Canadian Bee Journal, **43**(8): 215.

Dyce, E. J. 1931. Fermentation and crystallization of honey. Cornell University Agr. Expt. Sta. Bul. 528.

Clark, F. M. 1942. Honey fermentation—its cause and prevention. Illinois State Beekeepers' Assoc., 51 Annual Report.

Fabian, F. W., and **R. I. Quinet.** 1928. A study of the cause of honey fermentation. Michigan Agr. Expt. Sta. Tech. Bul. 92.

Killion, C. E. 1949. Removing moisture from comb honey. American Bee Journal, **90**(11): 14–6.

Lochhead, A. G. 1933. Factors concerned with the fermentation of honey. Zentl. Bakt. II, **88**: 296–302.

Lochhead, A. G., and **N. B. McMaster.** 1931. Yeast infection of normal honey and its relation to fermentation. Scientific Agriculture, **26**: 258–64.

Oertel, E. 1949. Honey and pollen plants in Louisiana. Bees, **3**(6): 4–5.

Richter, A. A. 1912. An osmophilous yeast, *Zygosaccharomyces mellis acidi*. Sp. n. Mycol. Centr., **1**: 67–76.

Root, H. H. 1918. Beware fermented honey. Gleanings in Bee Culture, **44**: 398–9.

Stephen, W. A. 1946. The relationship of moisture content and yeast count in honey fermentation. Scientific Agriculture, **26**: 258–64.

A New Generator for Producing Dry Aerosols with Organic Insecticides[1]

E. R. deOng, Kenneth C. Peer and L. W. Fancher[2]

Numerous methods of producing aerosol dispersions of organic insecticides in the atmosphere now exist. The high-pressure sprays, the fog-generators which employ heat and pressure, the "aerosol bomb" which employs as the propellant a halogenated hydrocarbon gas compressed into liquid in a metal cylinder and the hotplate onto which solutions of certain insecticides such as nicotine and benzene hexachloride are dripped, are examples of mechanical and physical means of producing aerosols. These methods all require the use of auxiliary solvents for carrying the active insecticidal agent in the aerosol particle.

The use of exothermic chemical reactions which produce sufficient heat and usually gaseous by-products to volatilize and propel organic insecticides into the atmosphere in finely-divided form has been referred to as "smoke aerosol" generation. This method is characterized by the absence of auxiliary solvents, the powdered reacting chemicals being admixed with the insecticide in the generator.

Many of the earlier "smoke aerosol" generators were of a combustion, or pyrotechnic, type, employing highly combustible cellulosic and other materials with additives of strong oxidizing agents such as nitrates, chlorates and the like to promote combustion. The temperatures of these combustion reactions are so high as to preclude their efficient use with thermally-unstable insecticides such as DDT, methoxychlor, chlordane, lethanes, and the like. Benzene hexachloride, being heat stable, is successfully dispersed in such combustion mixtures as a "smoke aerosol," characterized by the small particle sizes of the aerosol produced.

The term "dry aerosol" is preferred by the authors (the term "smoke aerosol" is redundant) to distinguish this type of aerosol from the mechanically and physically produced aerosol which contains auxiliary solvents.

The most recent and successful type of dry aerosol generator is that which uses a thermal decomposition of the contained chemicals to produce large volumes of water vapor and other gases which act as the propellants for the contained insecticides. They operate at much lower temperatures than the older combustion or pyrotechnic "smoke aerosol" generators. Since no true combustion occurs, and since large volumes of steam and other inert gases are evolved in a more or less self-regulating manner, the contained insecticides are literally "steam distilled" into the atmosphere. This later type of dry aerosol generator produces larger particle sizes in the aerosols than did the earlier combustion type.

The new generator presented here is of the thermal-decomposition type. (Fig. 1) The generator contains the insecticides

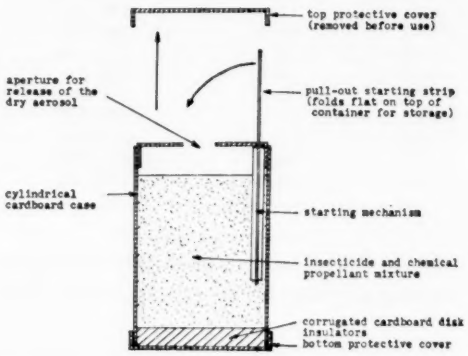

FIG. 1.—Schematic sketch of dry aerosol generator

in powdered admixture with the dispersing chemicals. On initiation by means of a starter strip of the friction match type, a chemical reaction occurs which first softens the insecticides by evolving heat, then propels the insecticides into the atmosphere by the evolution of steam and other insert gases. The reaction of the dispersing chemicals proceeds throughout the whole of the mass in an even, regulated manner. The temperature generated seldom exceeds 250° C., and the large vol-

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umes of steam protect the organic insecticides from decomposition as they are dispelled. A zone of live steam and hot gases carrying the insecticides as noted directly above the outlet of the generator during dispersion which is followed by a zone in which the steam condenses into fine droplets. These droplets are composed of water and insecticide and are about 5 microns in diameter. After most of the water evaporates in ordinary relative humidities after about 30 minutes, the aerosol particles begin to agglomerate and attain a particle

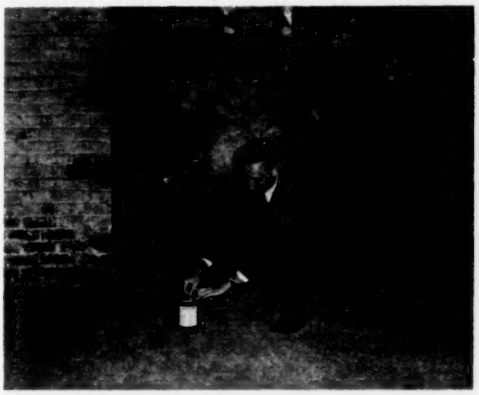

FIG. 2.—Starting the generator with the pull-out strip.

size of from 10 to 50 microns. (Figs. 2, 3, 4 and 5.)

Deposition of the aerosol particles on surfaces is followed by the growth of crystals, which, in the case of DDT, may reach a length of 200 microns in the longest dimension. The crystals of DDT deposited from the aerosol droplets project upwards from the surface, allowing maximum contact with the insects.

In the initial stage of the aerosol suspension in the atmosphere, the aerosol penetrates readily into microscopic openings in wood, fabric, etc., but after a few minutes will not penetrate fabrics of medium fine weave due to the increase in particle size. The residual deposited from the dry aerosol in an enclosed space is remarkably even over all surfaces, the concentration of the deposit being highest on horizontal surfaces (about 75 to 80 per cent) and lowest on vertical and inverted surfaces (about 20 to 25 per cent).

Insecticidal compounds such as DDT, chlordane, certain thiocyanates,[1] methoxychlor and of course, benzene hexachloride, can be dispersed by this method with

FIG. 3.—Dispersion beginning.

FIG. 4.—Dry aerosol dispersion after 30 seconds.

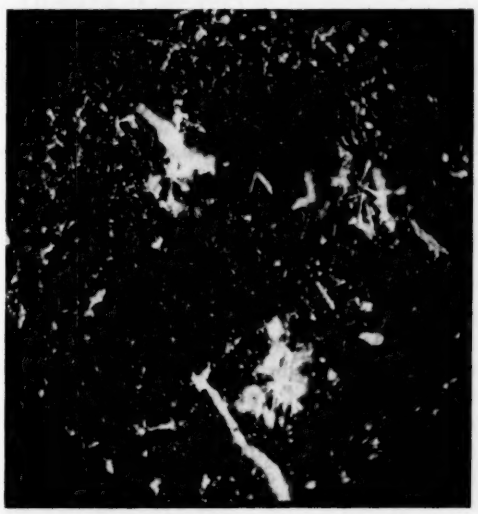

FIG. 5.—DDT crystals from dry aerosol deposited on bakelite surface—photomicrograph by reflected light—150×.

negligible decomposition. As a general rule, we have found that any organic com-

[1] *Lethane.*

pound which can be steam-distilled without undue decomposition may be dispersed as an aerosol by this method. Liquid compounds may be dispersed in formulations containing about 10 per cent by weight of the liquid, about 15 per cent solid organic compounds being present, if desired. Solids may be dispersed from formulations containing up to about 30 per cent by weight of insecticide.

The use of this type of dry aerosol generator is fairly general, being restricted to confined spaces. The economic advantage of being able to package the generator in ordinary untreated cardboard to provide a low-cost container of the "throw-away" type, the lowered shipping costs, the ease of operation without the continued attention of the operator, the lack of solvents, all indicate excellent application in providing space-kill and residual control of insects by the aerosol method at lowered cost to the user. Hazard of high-pressure containers is eliminated, and I.C.C. classification permits shipping with no special precaution.

Following are the data gathered from a series of laboratory and practical tests on insects, using this new dry aerosol generator.

SPACE KILL ON HOUSEFLIES.—10 grams of dry aerosol formulation was dispersed in a test chamber of 1000 cu. ft. capacity. The formulation contained 20 per cent DDT and 8 per cent of a thiocyanate,[1] by weight; therefore, about 2 grams of DDT and 0.8 grams of the thiocyanate[1] were dispersed. Houseflies were placed in wire cages 30 inches above floor level. Counts were made in chamber.

Results with houseflies have shown 100 per cent knock-down in 30 minutes and 100 per cent kill in 8 hours.

RESIDUAL TEST ON HOUSEFLIES.—Five grams of dry aerosol formulation were dispersed in a test chamber of 1000 cubic feet capacity. The formulation contained 20 per cent DDT and 8 per cent thiocyanate[2] by weight; therefore, about 1 gram of DDT and 0.4 gram of thiocyanate were dispersed. Wire cages with backs and sides of unpainted wood were exposed to collect residual. Adult houseflies were introduced into the exposed cages to test residual effect. Temperature 60° to 68° F.

Results of this test showed 100 per cent knockdown in 4 hours and 100 per cent kill in 5 hours.

After 6 days 78 per cent knockdown in 9 hours was observed but no kill was reported.

RESIDUAL TEST ON HOUSEFLIES AT REDUCED TEMPERATURES.—Five grams of dry aerosol formulation were dispersed in a test chamber of 1000 cubic feet capacity. The formulation contained 20 per cent DDT and 8 per cent thiocyanate by weight; therefore, about 1 gram of DDT and 0.4 gram of thiocyanate were dispersed. Wire cages with backs and sides of unpainted wood were exposed. Adult houseflies were introduced into exposed cages to test residual effect. Temperature of test 55° to 64° F. The test produced 100 per cent knockdown in 3 hours and 100 per cent kill in 12 hours.

COMPARATIVE TESTS ON RICE WEEVIL.—A series of tests were made on the confused flour beetle, *Tribolium confusum*, and the rice weevil, *Sitophilus oryza*, in a 1000-cubic foot chamber under controlled conditions, using various organic insecticides dispersed by the dry aerosol generator. The average temperature during the tests was 61° F. (range 60° to 64° F.). The insects were placed in circular wire screen cages (#30 mesh) at a height of 32 inches above the floor level. The dry aerosol generator was placed on the floor in the center of the chamber. Treating time was 4 hours, after which the cages were removed to a ventilated room at approximately the same temperature for observation.

Twenty to thirty weevils of both species were used for each test, normal adults being chosen, and controls held in the observation room. Both rooms were illuminated with four 40-watt daylight fluorescent lamps. All insects pronounced dead were retained 3 days and inspected for any signs of recovery.

The main object of this experiment was to determine the speed of action of the individual insecticides and combinations thereof on the grain weevil upon direct exposure. Cages placed with the screen openings in a vertical plane gave no different results than those placed in a horizontal plane. (Table 1.)

TEST ON WEEVIL-INFESTED RAILWAY GRAIN CAR.—A badly infested car having considerable loose grain piled in corners and other debris scattered on the floor,

[1] *Lethane 384.*
[2] *Lethane 384.*

was papered around the doors, as for cyaniding, no other preparation being made. Two test cages containing 28 healthy adult rice weevils in each were placed on the floor at either end of the car. A 1-pound dry aerosol generator containing 20 per cent DDT and 5 per cent chlordane was discharged and the doors of the car left closed for 24 hours, after which inspection and counts were made. (Table 2.)

Table 1.—Comparative tests on grain weevil.

Insecticide Dispersed	Quantity in Grams	Hours to 100% Moribund	Hours to 100% Kill
(1) DDT	9.0	48	63
Lethane 384	3.6		
Chlordane	2.7		
(2) DDT	24.0	16	43
Chlordane	6.0		
(3) DDT	36.0	24	70
(4) Chlordane	15.0	24	94
(5) *Lethane 384*	30.0	18	67
(6) Lindane	2.9	16	48
Lethane A-70	4.8		
(7) Lindane	3.2	10	48
(8) Toxaphene	20.0	70% in 45	recovered
(9) Methoxychlor	26.0	56% in 45	90% recovered
(10) Chloroacetophenone	5.0	12	36
DDT	20.0		
(11) b-b′ dichloroethyl ether	48.7	24	24
DDT	11.2		

TEST ON WEEVIL-INFESTED RAILWAY GRAIN CAR.—A railway grain car badly infested with confused flour beetle and saw-toothed grain beetle, *Oryzaephilus surinamensis*, was papered as for cyanide fumigation, the walls and floors being pounded to dislodge impacted grain. A 1-pound dry aerosol generator containing 18 per cent DDT, 5 per cent chlordane and 6 per cent lindane was discharged and the car left closed for 24 hours. The entire loose grain content of the car was swept up and collected in a tin which was transported to the laboratory immediately for counting. Visual inspection of the car showed no active weevils upon opening. Despite the papering of the car, bad leaking of the aerosol was observed. (Table 3).

Grain swept from the floor of railway grain cars after dry aerosol treatment exhibited residual action on insects (grain weevil, bean weevil) for 6 months when stored in the atmosphere at moderate temperatures.

Table 2.—Test on insect infested railway grain car.

Lapsed Time After Opening Car	Active	Moribund	Dead	Total
Rice weevil in test cages				
None	0	9	19	28
24 hours	0	0	28	28
Rice weevil from debris on car floor				
24 hours	14	17	37	68
48 hours	1 (weak)	19	48	68
Confused flour beetle from debris on car floor				
24 hours	0	14	104	118
48 hours	0	4	114	118
Saw-toothed grain beetle from debris on car floor				
24 hours	0	1	12	13
48 hours	0	0	13	13
Rice weevil from impacted hole in car wall				
24 hours	6	11	12	29
48 hours	0	17	12	29
Confused flour beetle from impacted hole in car wall				
24 hours	0	8	37	45
48 hours	0	1	44	45
Saw-toothed grain beetle from impacted hole in car wall				
24 hours	0	1	12	13
48 hours	0	0	13	13

The effective control indicated by the tests reported here and other tests not reported confirms the previously published suggestion that residual insecticides replace poisonous gas fumigation with hydrocyanic acid, methyl bromide, etc.[1] The advantages of the use of a dry aerosol generator for providing both space kill and residual action are several: (a) the lack of acute toxicity to workmen; (b) the ease of handling and application; (c) continued residual action of the insecticides to discourage re-infestation; (d) lack of auxiliary solvents reduces residual odor to negligible point and prevents loss of insecticide by soaking of solutions into surfaces of wood.

Table 3.—Test on insect infested grain car.

Lapsed Time After Opening Car	Active	Moribund	Dead	Total
Confused flour beetle				
4 hours	0	652	1858	2510
28 hours	0	0	2510	2510
Saw-toothed grain beetle				
4 hours	0	0	349	349

[1] U. S. Dept. Agr. Bur. Entom. & Plt. Quar. E-766 (1948).

Toxicity tests were made wherein rabbits and their food supply were enclosed in a chamber and subjected to twice the recommended dosage of dry aerosol for a period of 10 days. Examination showed no acute toxic effects. Respiratory irritation occurred in two of the 10 test animals on the eighth day, which disappeared after removal from the chamber. No chronic absorption and prolonged toxicity tests were made, but it is believed that the lack of auxiliary solvents contributes to lowered toxicity to warm-blooded animals. The authors and other laboratory personnel have been exposed to numerous aerosols of DDT, methoxychlor, benzene hexachloride, chlordane, and *Lethane 384* during a 5-year period without any acute or chronic toxic symptoms.

SUMMARY.—The term "dry aerosol" is proposed to describe an aerosol of insecticidal agent free of auxiliary solvents.

A new dry aerosol generator is described which propels the contained insecticides into the atmosphere in micron size particles without the use of solvents, compressed gases, or combustion processes.

The propelling agents in the new dry aerosol generator are certain inert gases and steam formed in the generator by the reaction of chemicals during the generating process.

The dry aerosol produced contains droplets of condensed water and insecticide which increase in size during suspension in the atmosphere. Following deposition of the aerosol droplets on surfaces, insecticide crystals form and enlarge, projecting upwards from the surface, allowing maximum contact with the insect.

Residual deposits are uniform, but vary in distribution, being highest on horizontal surfaces and lowest on vertical and inverted surfaces.

Most of the common residual organic insectides can be efficiently dispersed in dry aerosols by the new generator.

The new generator presents a low-cost, simplified method of space kill and residual control of insects in confined spaces. A choice of insecticides may be made to fit the particular infestation.

The use of dry aerosols for providing space-kill and residual protection against grain-eating insects in enclosed spaces is suggested to replace the more toxic gas fumigants such as hydrocyanic acid and methyl bromide, where contact with food materials can be minimized.

Laboratory and commercial tests show successful dispersion of insecticide, deposition of residual, and effective kill of insects, using various insecticides dispersed as dry aerosols by the new generator.

DR. JAMES A. BEAL TO HEAD FOREST INSECT WORK

Dr. James A. Beal was recently appointed as head of the United States Department of Agriculture's forest insect research and surveys, succeeding Dr. F. C. Craighead who retired after 27 years as leader of the Division of Forest Insect Investigations. Dr Beal, from his office at Beltsville, Maryland, will direct the work of 11 field offices located in important forest areas throughout the country. He graduated from the University of Massachusetts in 1923 and his graduate work in forestry and entomology at Syracuse University led to his M.S. degree in 1925 and to his Ph.D. in 1935. From 1926 to 1939 he had been connected with the Bureau of Entomology and Plant Quarantine's forest insect laboratories in both the east and west. He joined the faculty of the Duke School of Forestry in 1939 and for the past six summers he has worked for the Bureau of Entomology and Plant Quarantine under temporary appointments in various parts of the country.

SCIENTIFIC NOTES

Some Habitats of Eggs of *Aëdes vexans*[1]

M. T. Bodman[2] and Norman Gannon[3,4]

Eggs of the swamp mosquito, *Aëdes vexans* (Meig.), are deposited in certain areas subject to inundation. However, little information is available in the literature on types of habitats where eggs are found. Filsinger (1940) states that eggs were found in debris and in upper soil layers of sod samples. Information provided by a study of mosquito egg habitats would be helpful to agencies concerned with control based on prehatching treatment of potential larval sites. With this in mind, observations were made as an incident to other duties on the relative abundance of eggs in various habitats in Champaign County, Illinois during the fall of 1949. Areas selected were those subject to inundation by rainfall or overflow of streams. Most sites were in wooded areas where canopy shade was present. In such areas this shade was fairly complete in the early forenoon and late afternoon. The amount of shade was the least when the sun was at its zenith. One site was completely shaded by reeds and tall grass. Two were only slightly shaded part of the day while one was without canopy shade. Soil for the most part was clay loam with clay, muck and sandy gravel being represented.

Procedure.—At each site four or more collections were made by removing debris and soil from a spot 6 inches square to a depth of 2 inches. First the surface debris was removed, then successive layers of soil. Each layer was put into a separate carton for removal to the laboratory.

Relative abundance of viable eggs was determined by counting the number of larvae hatched from each sample. As a preliminary conditioning measure, routine practice consisted of placing all collections in a room where the temperature ranged between 70° and 74° F. for 7 to 10 days. After conditioning, all samples were submerged to a depth of an inch in a medium modified from one used by Horsfall 1949. The medium as used consisted of one part canned corn (cream style) in 200 parts of water. Hatching was carried out in the room and at the temperature stated above. Results are based on the number of larvae hatching in 48 hours. Larvae were reared to the last instar and identification verified.

Results.—Heavier soils are apparently more suitable for oviposition sites than are lighter soils. Where clay or clay loam soils were sampled the egg population reached a proportion of 32 per 100 sq. in. and occurred to a depth of 2 inches. None occurred in muck and sand samples even though other conditions were favorable.

[1] Contribution 296, Department of Entomology, University of Illinois.

[2] Illinois State Natural History Survey.
[3] University of Illinois.

[4] The constructive advice and criticism by Dr. W. R. Horsfall is gratefully acknowledged.

Table 1.—The relation between habitat and abundance of viable eggs of *Aedes vexans* Meigen, Champaign County, Illinois, 1949.

Station Number	Nature of Terrain	Kind of Soil	Shade	Debris Layer	Sample		Larvae Hatched	
					Depth, Inches	Number	Per Sample	Per 100 Sq. In.
1	Stream bank subject to overflow but not flat ground	Clay loam	Partial Canopy	Grass, leaves	0	4	0	0
					0–1	4	0	0
					1–2	4	0	0
2	Stream bank at point 2 feet below high water mark	San Gravel	Partial Canopy	Leaves	0	4	0	0
					0–1	4	0	0
					1–2	4	0	0
3	Bed of intermittent stream in open field	Clay	Absent	Grass	0	4	0	0
					0–1	4	0	0
					1–2	4	0	0
4A	Bed of slough 30 feet wide	Clay loam	Partial Canopy	Duff	0	16	96	16
					0–1	16	187	32
					1–2	16	51	9
4B	Same as 4A	Clay loam	Partial Canopy	Duff	0	4	34	24
					0–½	4	20	14
					½–1½	4	1	1
					1½–2½	4	0	0
5	Poorly drained	Clay loam	Partial Canopy	Duff	0	4	15	10
					0–1	4	6	4
					1–2	4	1	1
6	Railroad borrow pit	Clay loam	Complete Reed	Grass	0	4	0	0
					0–1	4	6	4
					1–2	4	0	0
7A	Bottom of bowl-shaped temporary pool	Muck	Slight Canopy	Leaves	0	4	0	0
					0–1	4	0	0
					1–2	4	0	0
7B	Side of bowl-shaped temporary pool	Clay	Partial Canopy	Leaves	0	4	3	2
					0–1	4	4	3
					1–2	4	1	1
8	Log in same area as #5-punky surface, solid heart	—	Partial Canopy	—	0–1	4	0	0

Larvae were found in connection with streams only when overflow land was present and were not found along streams not subject to overflow. In addition, a greater abundance of larvae was procured from samples taken from comparatively flat ground rather than from areas where the terrain was more variable. (Table 1, Station 4A.) Where the margin of a pool was steep without being vertical, oviposition was limited to a very narrow band about the edge. (Table 1, Station 7B.) Where vertical margins were present, as was the case in table 1, station 2, no eggs were found.

In every case eggs were present only in spots which had some form of shade. As the soil dries rapidly in this area when not shaded, soils iunder shade, either canoopy or reed, hold moisture longer than unshaded soils.

Table 2.—Horizontal distribution of the viable eggs of the swamp mosquito in the shallow bed of a woodland slough, Champaign County, Illinois, November, 1949.

Distance from Edge of Water to Site of Sample, Feet	Sample		Larvae Hatched, Number
	Number	Area, Square Inch	
5	1	36	31
10	1	36	69
15	1	36	1
20	1	36	0
25	1	36	2
30	1	36	5
35	1	36	43
40	1	36	0

Therefore, conditions which favor the retention of moisture allow oviposition to be accomplished over a greater length of time than would be afforded by unshaded quick-drying soils. These factors may explain the greater prevalence of larvae hatched from shaded clay or loam soils.

As seen in table 1, eggs are found at various depths in the soil. Filsinger 1940 found eggs in debris, in the first inch of soil, and below the first inch of soil to a depth of 6 inches. No further breakdown of the last four inches was given in his paper, however. Our data showed that eggs were present in the surface debris and down to a depth of 2 inches in some cases. Samples were not taken below 2.5 inches. For the most part eggs were found in the debris and in the first inch of soil. Since Filsinger's work was done in New Jersey, a possible explanation for the differences in soil depth penetration of eggs may be dependent upon soil differences between New Jersey and Illinois.

Eggs of the swamp mosquito were found irregularly distributed along the dry bed of a woodland slough as shown in table 2. Collections were made in November when the water level was at or near its lowest point for the season. The first sample was taken 5 feet away from the water while the remaining seven were taken at 5 foot intervals progressing up the bank. As table 2 shows, the eggs are concentrated into two bands, the first between 5 and 10 feet away from the water level present at the time of sampling and the second about 35 feet away. The rise in elevation from the first to the last sample was about 6 inches. These two bands probably indicate two different periods of oviposition.

There is no doubt but what the water level fluctuated between the spring and fall of the year. Therefore, it may be assumed that eggs were deposited slightly above the existing water level during both periods of oviposition.

Where the margin of the transient pool is steep, the band around it where eggs are deposited is very narrow. The station illustrating this consisted of a large bowl-shaped temporary pool with practically vertical sides and a muck covering of decaying leaves on the bottom. No standing water was present at the time of sampling. Only samples taken from a restricted ring about the edge on a 45 degree slope and a foot above the bottom level yielded any larvae (Table 1, Station 7A and B).

Summary.—Eggs of the swamp mosquito are deposited in areas subjected to inundation, but their locations are modified by other environmental features. Heavier soils are more suitable for oviposition sites than are lighter soils. Where the margin of transient pools is steep, the band around it where eggs are deposited is very narrow. Eggs are present only in spots which have some form of shade. These three situations play a part in affecting the retention of moisture for a longer period of time.

Literature Cited

Filsinger, Carl. 1940. Distribution of *Aëdes vexans* eggs. Proc. 28th Ann. Meet. New Jersey Mosquito Esterm. Ass'n. **28:** 12–19.

Horsfall W. R. 1949. Hatching eggs of floodwater mosquitoes in media that promote plant growth. Science **110**(2863): 504–6.

Cotton Injured by *Nysius californicus*

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Nysius californicus Stål., of the family of Lygaeidae, has frequently been collected on cotton. Records are available from several of the cotton States of the United States and from Mexico. In the past there has been little or no information to indicate that it actually caused damage to cotton.

During the summer of 1949 this insect was taken over a large area in the Laguna district in northern Mexico. Near San Pedro and Matamoros, Coah., *Nysius californicus* became very abundant in cotton fields about mid-June. In many fields it was possible to collect large quantities of these insects even without the aid of a net. Frequently farmers brought in as much as a half-pint jar full of the insects, which they had gathered by hand. The situation was the same in all the fields visited. The insects were found to be puncturing the squares and small bolls and sucking sap from the plants. Squares and bolls so attacked were soon shed by the plant. In some of the heavily infested fields all the squares and young bolls had been shed.

It seems unlikely that the damage could have been caused by anything other than *N. californicus*, since there were no other heavy insect populations present and the damage did not occur in fields where this insect was not present. Prior to the appearance of the insect there was little or no shedding by the cotton plants. The insect apparently migrated into the cotton fields, as it appeared in large numbers suddenly.

The insects were easily controlled by one or two applications of 10 per cent DDT dust. Following the control of *Nysius californicus* by insecticide the plants soon began to set and hold squares. However, during the remainder of the season the areas on the plants where shedding was heavy could be observed as having little or no fruit.

The Germinating Ability of Quick-Frozen, Bee-Collected Apple Pollen Stored in a Dry Ice Container

W. H. GRIGGS, *University of California*, and GEORGE H. VANSELL, and J. F. REINHARDT, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine, Davis, Calif.*

Bee-collected pollen can be readily obtained in almost unlimited quantities by the use of pollen traps. By careful selection of the time and place of trapping (Griggs and Vansell, 1949), it is possible to get nearly pure samples of any one fruit species. Previous studies have indicated that the viable storage life of this pollen is very short at room temperatures or in cold storage, ranging from a few hours (Singh and Boynton, 1949), to a maximum of two or three weeks (Kremer, 1949 and Griggs and Vansell, 1949). This rapid loss of viability has heretofore been considered one of the main handicaps in the use of bee-collected fruit pollen in artificial pollination.

In recent experiments at the University of California at Davis, quick-frozen samples of bee-collected apple pollen have given as high as 96 per cent germinability after seven months in a dry ice container. This increase in stability should assure future progress in the use of bee-collected pollen in artificial pollination. The idea of using dry ice for storing bee-collected pollen was suggested by the work of Bredemann *et al.* (1947), who preserved the viability of various hand-collected pollens for an unlimited time with liquid air refrigeration.

A bee hive equipped with a pollen trap was placed in a blossoming apple orchard in the Sierra foothills, April 26, 1949. The weather and blossom conditions were ideal for bee activity. The pollen pellets were removed from the trap at 30-minute intervals and put into 20 cc specimen vials which were immediately placed in a dry ice container. The lids of part of the vials were tightened in an attempt to exclude carbon dioxide; others were perforated to allow free entrance of the carbon dioxide. Each sample consisted of approximately 5 to 8 cc of pellets. At the end of the day the container with the samples was brought back to the laboratory where it was stored in a 4.2 cubic foot deep freezer. The freezer was adjusted to maintain a temperature of approximately −13 degrees C. without the addition of dry ice. The pellet container was kept packed with dry ice, and enough dry ice was packed around it in the deep freezer to maintain a temperature of about −51 degrees C. in the container. Approximately 40 pounds of dry ice were required weekly to maintain this temperature.

Table 1.—Germination of bee-collected pollen after seven months in dry ice storage.

MEDIUM	NO. SAMPLES TESTED	TOTAL NO. POLLEN GRAINS COUNTED	MEAN GERMINATION (PER CENT) AND STANDARD ERROR
Vials Sealed			
15% Cane Sugar, 2% Agar	14	1,947	82.7±6.22
20% Cane Sugar, 2% Agar	14	2,219	72.2±5.77
Vials Not Sealed			
15% Cane Sugar, 2% Agar	10	1,533	77.6±5.08
20% Cane Sugar, 2% Agar	10	1,888	66.5±5.61

The germinability of the pellet pollen was tested at monthly intervals. Two pellets from each vial were dispersed in 3 cc of freshly prepared 20 per cent cane sugar syrup. A smear was then made of the pollen-syrup mixture on an agar medium consisting of either 15 or 20 per cent cane sugar and 2 per cent agar. Experience has shown that much higher percentages of germination are obtained when fresh agar media are prepared for each testing. Table 1 shows the results of germination tests made on November 25, 1949, seven months after collection of the samples. The viability of the pollen will be further checked by using it to pollinate apple blossoms during the spring of 1950.

LITERATURE CITED

Bredemann, G., K. Garber, P. Harteck and Kl. A. Suhr, 1947. The effect of temperature on the viability of pollen. Naturwissenschaften 34(9): 279–80.

Griggs, W. H., and George H. Vansell, 1949. The use of bee-collected pollen in artificial pollinaton of deciduous fruits. Proc. Amer. Soc. Hort. Sci. **54:** 118–24.

Kremer, J. C., 1949. Germination tests of the viability of apple pollen gathered in pellets. Proc. Amer. Soc. Hort. Sci. **53:** 153–7.

Singh, Sardar, and Damon Boynton, 1949. Viability of apple pollen in pollen pellets of honeybees. Proc. Amer. Soc. Hort. Sci. **53:** 148–52.

Reactions of the Squash Vine Borer to Certain Insecticidal Soil Treatments[1]

W. L. HOWE *New York State Agricultural Experiment Station, Geneva*

In 1948 squash plants growing in soil treated with benzene hexachloride (6 per cent gamma isomer and 44 per cent other isomers) at the rate of 2 pounds gamma isomer per acre developed negligible squash vine borer, *Melittia cucurbitae* (Harris), infestations despite heavy oviposition. Examination of the plants revealed numerous dead first instar larvae inside shallow feeding lesions and in the leaf stalks. Taste tests of mature fruits showed the presence of off-flavors in the Hubbard variety, especially when steam-cooked under pressure. Off-flavors were less

[1] New York State Agricultural Experiment Station Journal Paper No. 825, April 7, 1950.

Table 1.—Effect of soil applications of insecticides on subsequent squash vine borer infestation. Geneva, New York, 1949.

	Mixture Applied[1]		Plot I 5 Varieties[2]			Plot II Blue Hubbard	
	Grams Insecticide per Hill	Grams 5–10–5 per Hill	Number Plants	Per Cent Injured	Per Cent Severely Injured	Number Plants	Per Cent Injured
Untreated	0	0	13	84.6	45.5	21	28.6
Untreated	0	250	13	92.3	15.4	20	25.0
Lindane	.25	250	16	18.7	0	18	5.6
Lindane	.50	250	15	0	0	20	0.0
Chlordane	.25	250	14	100.0	50.0	18	33.3
Chlordane	.50	250	14	85.7	64.3	22	27.3
Parathion	.25	250	12	75.0	8.3	22	22.7
Parathion	.50	250	16	93.7	31.2	22	27.3
Dieldrin	.25	250	14	71.4	14.3	21	14.3
Dieldrin	.50	250	10	60.0	30.0	22	4.5

[1] Applied June 17 as 250 grams .1% and .2% toxicant in 5-10-5 fertilizer in ring approximately one foot in diameter around base of each hill. Injury counts made October 10, 1949.
[2] Conn. Field Pumpkin, Warren Turban, Table Queen, Early Straightneck and Golden Delicious.

noticeable in Table Queen squash (*Cucurbita pepo*).

In 1949 seven hills of Golden Delicious Squash were planted in the same plot to determine whether soil residues of benzene hexachloride after one year's weathering were sufficient to cause larval mortality. Oviposition was moderate, larval mortality was observed, and no infestations developed in the plants.

Controlled tests were carried out in 1949 to confirm the 1949 observations if possible and to determine whether or not certain other organic toxicants created a similar larval response. Plants were forced in the greenhouse and set out into two plots on June 8 and 9. Plot I contained 50 hills with 5 varieties and Plot II contained 80 hills of Blue Hubbard squash. Each hill in both plots consisted of approximately three plants. Four insecticides, as indicated in table 1, were incorporated with a 5-10-5 fertilizer at rates of 0.1 and 0.2 per cent actual toxicant by weight. On June 16, 250 grams of the fertilizer mixture was applied in a small ring approximately 1 foot in diameter around the base of each hill. The mixture was then worked into the surface soil. Dosages were small and limited in area, so that only the less extensive root system of the young plants would be exposed to the toxicant, while the greatly expanded root system present during fruit set would be drawing nutrients largely from untreated soil. Rainfall was depended upon to wash the insecticides into the soil. Squash vine borer oviposition was first observed on July 1, and egg hatching began about 1 week later. On October 3, final injury counts were made on both plots. The results are reported in table 1.

With the possible exception of dieldrin, only lindane caused larval mortality. Infestations in plot 1 were light; those in plot 2 were moderate to severe. Larvae attacking plants growing in lindane treated soil died after a small amount of boring. If they were able to penetrate the hollow leaf petiole they were usually found dead near the point of entry.

Later, applications of 2 grams of lindane per hill were made by applying 2 gallons of a wettable powder suspension around the bases of extra hills containing larvae of all stages. This treatment resulted in 100 per cent mortality of all larvae within 5 days.

Even though small quantities of lindane in the soil around preferred hosts caused high larval mortality and greatly reduced plant injury, its value as a control measure appears to be doubtful due to dangers of causing off-flavors and unfavorable changes in fruit texture and shape.

Control of White Grubs in Nursery Plantings[1]

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White grubs frequently become sufficiently abundant to cause serious losses to young coniferous trees in commercial nurseries, reforestation and state forest tree nursery plantings. Heit & Henry (1940) report severe injury by 6 species of phytophagous scarabeoid grubs to the roots of coniferous seedlings and transplants in a forest tree nursery. In addition, these workers observed that one species, *Diplotaxis sordida* Say, was injurious in the adult stage to the foliage of Scotch pine, *Pinus sylvestris* L. Schwardt (1942) observed injury to young hemlock trees by white grubs in the nursery planting.

For the most part there seems to be a definite association between grub damage and soil type. Generally speaking, in New York injury caused by several species of "white grubs" has been observed on conifers which were growing in the lighter or gravelly soil types such as Arkport fine sandy loam, Dunkirk silty clay loam, Culver stony silt loam. The years in which serious damage occurred and the species or group of species of grubs which are predominant have been shown by Heit & Henry (1940) and Kerr (1941) to vary in different parts of the state. In western New York, particularly in Niagara County, the authors have observed that serious damage occurred to young conifers in the nursery planting during 1944 and 1947 from such species as *Phyllophaga rugosa* (Melsh.). The rose chafer, *Macrodactylus subspinosus* (Fab.) was frequently associated with the white grubs. During these years

[1] Journal Paper No. 821, New York Agricultural Experiment Station, Geneva, New York, March 10, 1950.

Table 1.—White grub and rose chafer control. Chemicals applied October 2, 1948 as a surface application in water. Records obtained February 17, 1949, some 16 weeks after treatment. Soil temperature varied from 45–60° F.

Material	Dosage per Acre Active Ingredient	Per Cent Grubs Dead			Per Cent Grub Control		
		White Grubs			White Grubs		
		Second Instar	Third Instar	Rose Chafer	Second Instar	Third Instar	Rose Chafer
1948							
Lead arsenate	500 lbs.	66	76	100	60	66	100
Chlordane, 40% wettable powder	20	96	80	98	95	72	97
Chlordane, 40% emulsifiable	20	—	96	99	—	94	98
Chlordane, alcohol emulsion[1]	20	—	—	100	—	—	100
Chlordane, ethylene dichloride emulsion[2]	20	100	80	100	100	72	100
DDT, 1% dust	50	54	8	66	45	0	39
Parathion, 1% dust	15	—	88	100	—	83	100
Benzene hexachloride, 1% (gamma), dust	5	96	—	99	95	—	98
Hydrated lime	2000	25	11	39	11	0	0
Ethylene dichloride emulsion[3]	20 gal.	100	100	99	100	100	98
Check	0	16	29	45	—	—	—
1949							
Benzene hexachloride (gamma isomer)	5 lbs.	—	—	—	94	—	93
Check	none	—	—	—	19	—	—

[1] Technical chlordane 1.5 grams, 95% ethyl alcohol 8.25 grams, Tween-20 0.25 gram.
[2] Technical chlordane 1.5 grams, ethylene dichloride 8.25 grams, Tween-20 0.25 gram.
[3] Formulation recommended by U. S. Department of Agriculture in "Treating procedures for use as a basis for certification of products regulated by Japanese beetle," page 32, June 2, 1947.

such plants as Colorado blue spruce, Pfitzer and Savin junipers showed considerable injury, but *Taxus* spp. were less seriously damaged. For example, records obtained November 4, 1947, showed that 68 per cent of 4-year old, once transplanted, stock of Savin juniper were injured to some extent. Similarly, during November 1949, approximately 20 per cent of 6-year old Colorado blue spruce were either dead or displayed typical signs of grub injury. During the 2 to 4 years in which coniferous seedlings and rooted cuttings are grown in shaded lath houses, nurserymen have not experienced any serious difficulty from white grubs, but in some instances the root weevils, *Brachyrhinus ovatus* L. and *B. sulcatus* Fab., feed upon the roots and bark below the surface of the soil on such conifers as *Taxus*, Douglas fir, Canada hemlock and Spiny Greek juniper.

During the fall of 1947 a series of preliminary tests was started to obtain information on the value of such insecticides as benzene hexachloride, DDT, chlordane, parathion, ethylene dichloride and lead arsenate upon the control of white grubs and of the rose chafer. Grubs of both species were placed in soil among rooted cuttings of Parson's arbor vitae which were growing in greenhouse flats under lath houses. These materials were diluted at the rates indicated in table 1 and applied as a surface application. Approximately 250 plants, in two flats, of Hatfield yew, Spiny Greek, Swedish, Pfitzer and Savin junipers, Woodward's, pyramidal and Parsons' arbor vitae, Douglas fir, and Canada hemlock were treated with these same materials. All of these materials showed promise in the control of grubs. With the possible exception of benzene hexachloride, no deleterious effects were noticed upon plant growth over a period of 18 months.

Hammond (1949) showed that benzene hexachloride was effective against second year third-instar white grubs. On October 2, 1948 a second series of grub toxicity studies was begun. Both white grubs and rose chafter grubs were used in this test. The insecticides were diluted as shown in table 1. Dunkirk silty clay loam soil was placed in wooden greenhouse flats and a definite number of grubs (25 or 50 depending upon the species) was put in the soil of each flat. Following this the soil was seeded with a commercial mixture of lawn grass. Twenty-four hours later the soil in these flats was treated with the various insecticides. They were applied either as a suspension or an emulsion, depending upon the formulation, on the surface of the soil with a sprinkling can at the rate of 1 gallon of the mixture per square yard of area. Following treatment the flats were held in the greenhouse at a temperature of 45° to 60° F. for a period of 16 weeks. The results obtained from these treatments are given in table 1.

Beginning October 7, 1949 a similar series of experiments was conducted in which lead arsenate, DDT, benzene hexachloride, chlordane and parathion were intimately mixed with Dunkirk silty clay loam soil. Following the mixing process the soil was put into boxes 18 by 18 by 5 inches and 25 or 50 white grubs (second and third instars, respectively) were placed in each box. Grass seed was mixed with the surface layer of soil to serve as food for the grubs at the beginning of the experiment and following each examination. Records of mortality were taken at weekly intervals. The rate of application per acre of the various insecticides and of grub mortality at several intervals following treatment is given in table 2.

DISCUSSION OF RESULTS.—The preliminary studies during both 1947 and 1948 indicated that such insecticides as benzene hexachloride, chlordane, and parathion were toxic to second and third instar *Phyllophaga* grubs and to third instar rose chafer grubs. In these tests DDT was noticeably less effective than the preceding materials on both species of grubs. Lead arsenate gave somewhat better control than DDT on white grubs and afforded excellent control of rose chafer during the 1948 tests but was less effective in experiments conducted during 1949. Ethylene dichloride emulsion gave almost complete control of both species of grubs when applied as a surface treatment on flats but it is doubtful if such a treatment would prove practical except under lath house conditions. Grass seed germinated and grew at about the same rate on treated and untreated soils, except when benzene hexachloride was mixed in a soil of low organic content. In the 1947 treatments, where benzene hexachloride was

Table 2.—Soil treatments for control of white grubs. Greenhouse studies, Stedman Nurseries, Newfane, N. Y. Winter 1949–50. 250 grubs were used in each treatment.

Treatment	Rate per Acre Lbs.	Per Cent Mortality, Weeks After Treatment									
		2	3	4	5	6	7	8	9	10	13
Experiment No. 1—Held at 50–60° F.±											
Chlordane	20	76	98	100							
γ Benzene hexachloride	5	82	97	98	100						
Parathion	15	83	97	99	99	100					
DDT	50	3	34	60	71	81	91	94	98	99	100
Lead arsenate	500	3	14	24	27	31	32	38	40	42	48
Check	none	3	9	15	20	22	23	25	29	30	37
Experiment No. 2—Held at 40–50° F.±											
Chlordane	20	70	81	88	93	96	100				
γ Benzene hexachloride	5	74	83	91	96	98	99	100			
Parathion	15	90	97	100							
DDT	50	24	42	52	60	74	88	94	96	98	100
Check	none	4	7	11	11	13	14	14	15	15	18

applied on the surface of the soil in which several types of conifer seedlings and cuttings were planted, there was some suggestion of a reduction in growth at the time the experiment was terminated some 18 months later.

The tests conducted in greenhouse flats during the fall and winter of 1949–50 showed that both second and third instar white grubs were quite susceptible to such chemicals as benzene hexachloride, chlordane, and parathion at the dosages used. With the exception of parathion the rate of kill was somewhat more rapid at a soil temperature of 50 to 60° F. than at 40 to 50 °F. DDT was noticeably slower in its killing action than were the other materials first mentioned but did afford a higher kill than lead arsenate during the same period of time. Under nursery conditions where rapid kill of grubs is essential to the protection of nursery stock, such materials as chlordane, parathion or benzene hexachloride show considerable promise when intimately mixed with the soil.

Summary. Benzene hexachloride, chlordane and parathion have shown a high degree of efficiency in the control of second and third instar white grubs and of rose chafer grubs at dosages of 5 pounds (gamma isomer), 20 pounds, and 15 pounds per acre, respectively, when intimately mixed with the soil and used under greenhouse conditions. Except for possible slight retardation with benzene hexachloride these materials did not cause any appreciable injury on such conifers as Hatfield's yew, Passon's, pyramidal and Woodward's arbor vitae, Savin, Pfitzer, Spiny Greek and Swedish junipers, Canada hemlock and Douglas fir when such plants were growing in greenhouse flats over a period of 18 months

DDT was intermediate in killing action between lead arsenate and such materials as benzene hexachloride, chlordane, and parathion. Under nursery conditions where a rapid kill of grubs is essential to protection of young rooted cuttings and seedlings, benzene hexachloride, chlordane and parathion show promise. Thus far these insecticides have not been tested by the writers under commercial conditions but further experiments will be conducted during the 1950 season to determine residual action of these chemicals in the soil and their effect upon the growth of a number of species and varieties of coniferous trees.

Literature Cited

Hammond, G. H. 1949. Benzene hexachloride as a rapid control agent for white grubs (*Phyllophaga* spp.). Canad. Ent. LXXXI: 200–1.

Heit, C. E., and H. K. Henry. 1940. Notes on the species of white grubs present in the Saratoga forest tree nursery. Jour. Forestry **38:** 944–48.

Kerr, T. W., Jr. 1941. Control of white grubs in strawberries. Cornell Univ. Agr. Expt. St. Bul. **770:** 10–11.

Schwardt, H. H. 1942. Control of native white grubs in young hemlocks. Jour. Econ. Ent. **35:** 176–77.

Experiments in Control of the Pecan Weevil

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Experiments to determine the effectiveness of sprays containing benzene hexachloride, chlordane, DDT, DDT plus parathion, lead arsenate, parathion or toxaphene against the pecan weevil, *Curculio caryae* (Horn), were conducted in central Texas from 1946 to 1949. Lead arsenate had in earlier years given considerable reductions in weevil infestation (Nickels & Pierce 1946).

Cage Tests.—Detailed tests were carried on in 1946 in small cages. On September 12 nut-bearing branches that had not been treated were sprayed with benzene hexachloride or DDT. After the spray had dried, a wire-screen cage 8 inches in diameter and 24 inches long was placed over each branch. Ten female beetles were then placed in some of the cages and 10 males in others. All the beetles were obtained by jarring pecan trees. On September 23 the cages were examined. The results given in table 1 show that spray applications of DDT and benzene hexachloride caused high mortality and considerable reduction in feeding by the pecan weevil.

Field Experiments.—In field experiments the sprays were timed by observations on weevil emergence. The weevils are present in the ground during

Table 1.—Toxicity of benzene hexachloride and DDT sprays to pecan weevils in cages, Brownwood, Tex., 1946.

Materials	Pounds per 100 Gallons	Females			Males		
		Weevils Used	Per Cent Dead	Feeding Punctures	Weevils Used	Per Cent Dead	Feeding Punctures
Benzene hexachloride, wettable powder, 5% gamma isomer	6	49	94	66	30	100	22
DDT, 50% wettable powder	5	49	100	30	50	100	8
Check	—	47	28	283	47	60	67

the summer, and usually emerge late in August or in September. If during this period the weather is dry, most of the weevils do not come out of the ground until later, after the rains begin. When weevil-injured nuts were observed, 5 to 10 trees were jarred to determine whether enough weevils were present to make spraying worth while. Spraying was done with a power machine, from the ground or from the top of the sprayer tank, at a pressure of 500 to 600 pounds per square inch. A single-head gun was used. The experiments were conducted in randomized blocks, usually with 9 or 10 one-tree replicates. The proportion of huts infested by weevils was determined for a representative sample of 250 nuts harvested from each tree.

In 1946 field experiments with benzene hexachloride and DDT were conducted at Gustine, Texas, on the Western variety of pecans. The trees bore a light crop of nuts, and the infestation of pecan weevils was abnormally heavy. Three applications of the insecticide were made—on September 2, 10, and 19. The results are given in table 2.

Table 2.—Effectiveness of benzene hexachloride and DDT sprays for control of the pecan weevil, Gustine, Tex., 1946.

Materials	Application No.	Quantity per 100 Gallons	Harvested Nuts Infested
		Pounds	*Per Cent*
Benzene hexachloride wettable powder, 5% gamma isomer	1	6	97
	2, 3	4	
DDT, 50% wettable powder	1–3	5	92
Check	—	—	96

Table 3.—Effectiveness of DDT and lead arsenate sprays for control of the pecan weevil, Brownwood, Tex., 1947.

Materials	Quantity per 100 Gallons	Harvested Nuts Infested
	Pounds	*Per Cent*
DDT, 50% wettable powder	6	2
Lead arsenate	6	4
Hydrated lime	6	
Zinc sulfate	2	
Check	—	15

In 1947 two experiments with DDT and lead arsenate sprays were carried on, one at Brownwood and the other at San Angelo.

At Brownwood the variety used was Burkett, and the trees had received no spray treatments during the preceding two years. Three applications were made—on August 29 and September 9 and 20. The first two were well timed. The last one was late, and probably contributed little to the control obtained. The results are given in table 3.

Aphids (*Monellia* sp.) had been abundant prior to the beginning of these experiments. To control these aphids tetraethyl pyrophosphate was included in the first spray treatment on August 29. At the strength used (8 fl. oz. of 11.2 per cent material with summer oil, 2 quarts per 100 gallons) this insecticide was not highly effective. Nicotine sulfate 40 per cent (8 fl. oz. with summer oil, 2 quarts per 100 gallons) was included to control aphids in the second spray treatment, with better success.

The experiment at San Angelo was on the Western variety of pecans. Single spray applications of chlordane, DDT, toxaphene, or lead arsenate were made on September 4. In this orchard the weevil infestation has frequently been high when rainfall late in August or early in September was favorable to the emergence of the beetles. In 1947, however, there was little rain until October 9, when about 1 inch fell. At this time the shucks on the Western variety were beginning to open. On October 21, 46 per cent of the nuts on unsprayed trees had been punctured by weevils, but the nuts were so advanced in development that few eggs had been deposited by the late weevils. Most of the weevils that had emerged at the normal time had died before this belated emergence took place. At harvest, in December, very small larvae were present in about 7 per cent

Table 4.—Effectiveness of chlordane, DDT, lead arsenate, and toxaphene sprays for control of the pecan weevil, San Angelo, Tex., 1947.

Materials	Quantity per 100 Gallons	Harvested Nuts Infested
		Per Cent
Chlordane, 44% emulsion concentrate	1 qt.	8
DDT, 50% wettable powder	6 lb.	2
Toxaphene, 18.2% wettable powder	9 lb.	8
Lead arsenate	6 lb.	4
Check	—	11

of the nuts. Since practically all of them came from weevils that had emerged abnormally late, and since the sprays were timed for normal emergence, the records of the late weevils have been excluded. The results of these tests are given in table 4.

Experiments in 1948 were conducted with chlordane, DDT plus parathion, and parathion at Lamkin, Tex., on four Burkett and six Western pecan trees for each treatment. Sprays were applied on September 3 and 13. Results are given in table 5. The figures represent the averages of infested nuts for the two varieties.

Table 5.—Effectiveness of chlordane, DDT plus parathion, and parathion sprays for control of the pecan weevil, Lamkin, Tex., 1948.

Materials	Quantity per 100 Gallons	Harvested Nuts Infested
		Per Cent
Chlordane, 74% emulsion concentrate	3 pts.	3
DDT, 50% wettable powder Parathion, 25% wettable powder	6 lb. 2 lb.	2
DDT, 50% wettable powder Parathion, 25% wettable powder	6 lb. 8 oz.	0
Parathion, 25% wettable powder	3 lb.	2
Check	—	20

Experiments in 1949 were conducted at Lamkin, Tex., on six Burkett pecan trees for each treatment with DDT, and with DDT plus parathion. The single-spray treatment was applied on September 7. Results are given in table 6.

Table 6.—Effectiveness of DDT, and DDT plus parathion sprays for control of the pecan weevil, Lamkin, Tex., 1949.

Materials	Quantity per 100 Gallons	Harvested Nuts Infested
		Per Cent
DDT, 50% wettable powder	6 lb.	6
DDT, 50% wettable powder Parathion, 15% wettable powder	6 lb. 3 lb.	4
Check	—	55

In field experiments at Gustine, Texas, in 1946, DDT and benzene hexachloride were ineffective in the control of a heavy weevil infestation attacking a light nut crop.

At Brownwood, Texas, in 1947, DDT and lead arsenate were effective in the control of a light weevil infestation. At San Angelo, Texas, DDT was the most effective spray and lead arsenate next in importance; chlordane and toxaphene were not highly effective.

At Lamkin, Texas, in 1948, chlordane, used at a greater strength than in 1947, was more effective in weevil control. Parathion used alone was effective in the control of a light infestation of the pecan weevil. Parathion plus DDT appeared to be a little more effective than chlordane. At Lamkin in 1949, single applications of DDT and DDT plus parathion were effective in the control of a moderate infestation of the pecan weevil.

None of the spray mixtures caused any visible injury to the trees. When used with lime and zinc sulfate, lead arsenate rarely caused injury to pecan foliage in a semiarid climate.

Literature Cited

Nickels, C. B., and Pierce, W. C. 1946. Effect of lead arsenate sprays on the pecan weevil and other pecan insects. JOUR. ECON. ENT. 39(6): 792–94.

Insecticidal Action of American Species of *Heliopsis*[1]

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The isolation from the roots of the Mexican plant *Heliopsis longipes* (A. Gray) Blake of an amide toxic to certain insects (Acree *et al.*, 1945, Jacobson *et al.* 1947, McGovran *et al.* 1947) prompted an investigation of the insecticidal value of several species of this genus that are native to the United States. This paper reports results obtained with extractives of samples of three species.[2] The chemical phases[3] of the work will be discussed elsewhere.

The air-dried whole plants of two species, *Heliopsis scabra* Dunal. (obtained in the Ruidoso Canyon, White Mountains of New Mexico) and *H. gracilis* Nutt. (obtained near Channel View, Texas), were separated into stems, roots, leaves, and flowers. The third species, *H. parvifolia* A. Gray (obtained at Marathon, Texas), was nearly devoid of flowers, and only the stems, roots, and leaves were separated. Each part was finely ground[4] and extracted successively in a soxhlet extractor with petroleum ether (b.p. 30–40° C., Skellysolve A), ethyl ether, and chloroform. Extraction with each solvent was continued for at least 18 hours. The extracts were then completely freed of solvent under reduced pressure.

The extractives were incorporated in kerosene sprays at a concentration of 25 mg. of extractive per milliliter of spray. When it was necessary in order to dissolve the material completely, acetone was used as an auxiliary solvent. Pyrethrum standards of comparison were prepared from a concentrate, chemical analysis of which showed pyrethrin I and cinerin I to comprise 54 per cent of the "total pyrethrins."

Tests were made by the turntable method to determine the comparative toxicity of these sprays to adult house flies, *Musca domestica* L., reared in the laboratory by standard procedure. Knockdown and mortality percentages were determined in tests replicated two or three times. Approximately 100 flies averaging 2 days in age were used in each test.

The materials were prepared at different times, therefore the tests were made on different populations of flies. Since mortalities in different series are not comparable, a pyrethrum standard was included in each series. The results in terms of relative

[1] Preliminary report of a study made under the Research and Marketing Act of 1946.

[2] The plant materials were collected by A. H. Berkman of Texas Western College, and H. R. Reed of Sonora, Texas.

[3] Performed by Martin Jacobson of the Bureau of Entomology and Plant Quarantine.

[4] In a Wiley mill.

toxicity of each spray as compared with pyrethrins are given in table 1.

Since acetone in kerosene sprays increases the effect of many toxicants, sprays containing acetone were compared with standards in which acetone had been incorporated at the same concentration. Because knockdown effect especially is increased by the presence of acetone in the spray, these results are not given in the table. However, knockdown was correlated with mortality; the higher the mortality, the higher was the knockdown value. The toxic principles of these plants themselves caused knockdown.

Table 1.—Toxicity to house flies of extractives from different portions of three species of *Heliopsis*. Concentration in all sprays was 25 mg. per ml.

Species and Portion of Plant	Extractant	Per Cent of Material Extracted	Concentration of Pyrethrins (Mg./Ml.) Showing Equal Toxicity
Heliopsis scabra:			
Roots	Petroleum ether	1.6	>2
	Ethyl ether	0.6	1
	Chloroform	0.8	1
Stems	Petroleum ether	0.6	2
	Ethyl ether	0.4[1]	
	Chloroform	0.5[1]	
Leaves	Petroleum ether	2.3	2
	Ethyl ether	1.9	<1
	Chloroform	0.9	<1
Flower heads	Petroleum ether	7.3	<1
	Ethyl ether	0.9[1]	
	Chloroform	0.9[1]	
H. parvifolia:			
Roots	Petroleum ether	0.6	>2
	Ethyl ether	0.4	<1
	Chloroform	0.8[1]	
Stems	Petroleum ether	0.9	1
	Ethyl ether	0.8	<1
	Chloroform	0.9[1]	
Leaves	Petroleum ether	1.8	2
	Ethyl ether	1.5	<1
	Chloroform	1.5[1]	
H. gracilis:			
Roots	Petroleum ether	0.4	>2
	Ethyl ether	0.5[1]	
	Chloroform	0.8[1]	
Stems	Petroleum ether	0.4	1
	Ethyl ether	0.6[1]	
	Chloroform	0.6[1]	
Leaves	Petroleum ether	1.8[1]	
	Ethyl ether	1.7[1]	
	Chloroform	3.2[1]	
Flower heads	Petroleum ether	2.0	>2
	Ethyl ether	0.9[1]	
	Chloroform	2.4[1]	

[1] Little or no toxicity shown by this material.

The results show that these species of *Heliopsis* contained material toxic to house flies. Practically all of it was extracted by petroleum ether. In all three samples it was concentrated in the roots. It was also concentrated in the flower heads of *H. gracilis*, but in the flower heads of *H. scabra* in relatively small amount only. It was found in moderate amount in the stems of all three samples. Moderate amounts were found in the leaves of *H. scabra* and *H. parvifolia*, but none was found in the leaves of *H. gracilis*.

Further work is in progress on the toxic constituents of these plants.

Literature Cited

Acree, F., Jr., M. Jacobson and H. L. Haller. 1945. Jour. Organic Chem. **10**: 236, 449.

Jacobson, M., F. Acree, Jr., and H. L. Haller. 1947. Jour. Organic Chem. **12**: 731.

McGovran, E. R., G. T. Bottger, W. A. Gersdorff, and J. H. Fales. 1947. U. S. Bur. Ent. and Plant Quar. **E-736.**

Insect Eggs Transported on the Outer Surface of Airplanes[1]

John E. Porter[2] and John H. Hughes[3,4]

The Public Health Service recorded finding of insect eggs on the outer surface of an airplane that arrived at Miami, Florida, from Natal, Brazil, as early as January 1943. On July 16, 1946, insect eggs were again taken from the outer surface of an airplane that arrived in Miami from San José, Costa Rica, and Havana, Cuba. The eggs in both instances belonged to the moth family Phalaenidae (Noctuidae). Buren (1948) reported that this unusual means of insect egg transportation was also observed at Miami in 1947. The latter observation was made on a plane that originated its flight in Rio de Janeiro, Brazil, and made stops at several ports before arriving at Miami. The first instar larvae from these eggs were also identified as members of the family Phalaenidae.

Recently, Senior-White and Kirkpatrick (1949) recorded viable Noctuidae on an airplane that arrived at Trinidad, British West Indies, from Rio de Janeiro, en route to Miami.

During the 9-month period April 1, 1949, through December 31, 1949, the Miami Quarantine Station examined the exterior of 9,055 planes for insect egg masses, finding them on 78 (7.8 per cent). These inspections were in addition to the thousands made in the interior of planes for arthropods of public health importance. Table 1 gives some of the information obtained as a result of the inspections. As may be seen in the table, numerous ports in South America and the Caribbean region have been contacted by the planes on which insect eggs have been found. Although it is difficult to determine the point of origin of the insect eggs on these planes, it is probable that they were deposited at various airport stops along the routes and at Miami. However, in a number of instances the eggs were recorded with a degree of certainty as having come from foreign ports, since they were taken from planes that had been inspected and found free of eggs before last departing from Miami for foreign ports. The planes that arrived in Miami from Rio de Janeiro and associated ports of call were carefully observed; records of their travel show that on only two occasions during the aforementioned 9-month period

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[4] The authors are indebted to Henry Kaplan, Biological Aide, Quarantine Station, U. S. Public Health Service, Miami Beach, Florida, for his valuable assistance.

did a plane on which insect eggs were found make more than one trip within a single month. It is quite definite, therefore, that eggs were deposited on these planes prior to their arrival at Miami.

Insect eggs have been found at Miami on plane propellors, various parts of the fuselage, the under sides of the wings, and on the tail assembly. The moths apparently are attracted equally to painted and unpainted aluminum and canvas surfaces. However, there was an absence of eggs from the surfaces that had been smudged with oil from the motors.

If it is true that eggs are not laid on the oil-coated surface of a plane, this observation should merit consideration by persons interested in developing control measures for this type of insect transportation.

The number of egg masses observed on a plane ranged from 1 to approximately 1000. A Dominican Republic AAF plane inspected had thousands of larvae which had emerged from the egg masses and were observed crawling on the surface of the plane, which was parked approximately 10 feet from vegetation. The wind could have blown hundreds of the

Table 1.—Insect egg findings on the exterior of planes arriving at Miami, Florida, from foreign ports, April 1–December 31, 1949.

PORTS OF ORIGIN	PORTS OF CALL	NO. PLANES CARRYING EGGS	DETERMINATIONS MADE FOR EGGS FOUND
Rio de Janeiro	Anapolis, Carolina, Belem, Paramaribo, Port of Spain, LaGuaira, Ciudad Trujillo	20	*Laphygma frugiperda*; *Laphygma exigua*; Probably Phalaenidae; Probably *Laphygma frugiperda*
Rio de Janeiro	Anapolis, Carolina, Belem, Panama City, Port of Spain, LaGuaira, Ciudad Trujillo	1	Phalaenidae sp.
Rio de Janeiro	Anapolis, Carolina, Belem, Paramaribo, Port au Prince, LaGuaira, Ciudad Trujillo	4	Not identified
Rio de Janeiro	Anapolis, Carolina, Belem, Paramaribo, Port of Spain, Ciudad Trujillo	1	Phalaenidae sp.
Rio de Janeiro	Anapolis, Carolina, LaGuaira, Ciudad Trujillo	1	Phalaenidae sp.
Rio de Janeiro	Anapolis, Carolina, Belem, Port au Prince, LaGuaira, Ciudad Trujillo	2	*Laphygma frugiperda*
Havana	———	29	Phalaenidae sp.; *Prodenia ornithogalli*; *Laphygma frugiperda*
Kingston	———	2	Phalaenidae sp.; *Prodenia ornithogalli*
Ciudad Trujillo	———	1	*Laphygma frugiperda*
Port au Prince	———	1	Phalaenidae sp.
Maracay	Ciudad Trujillo, Camaguey	1	Phalaenidae sp.
Maracay	———	2	Phalaenidae sp.; *Prodenia* sp.; *Prodenia dolichos*
Guatemala City	———	2	Phalaenidae sp.
Barranquilla	———	2	Phalaenidae sp.
Caracas	———	1	Not identified
Medellin	———	2	*Laphygma frugiperda*
Tegucigalpa	———	2	Not identified
San José	———	3	Phalaenidae sp.
Lisbon, Portugal	Hamilton, Bermuda	1	Not identified
Total		78	

larvae to this vegetation, on which they could have fed. The depositing of newly-emerged larvae on grass in airport areas, particularly where these plant pests have not become established, could present a serious economic problem.

Sanitary inspectors on duty at the airport removed insect eggs from airplane surfaces by means of a sharp-bladed instrument and transmitted them to the laboratory for study.

Viable eggs were permitted to hatch, and the larvae were reared in the laboratory to facilitate their identification. The larvae were fed on various types of food, including lettuce, grasses, fig leaves, and sapodilla fruit. They ate lettuce readily, but completed their life cycles in less time when fed on fig leaves and sapodilla fruit.

All material identified belonged to the family Phalaenidae.[1] The predominant species was the fall armyworm, *Laphygma frugiperda* (A. and S.), common in our southern states, the West Indies, and Central and South America. The eggs of *Laphygma exigua* (Hbn.), *Prodenia dolichos* (Fabr.), and *Prodenia ornithogalli* Guen. were also found on planes.

SUMMARY.—Viable insect eggs of the economic species *Laphygma frugiperda, Laphygma exigua, Prodenia dolichos,* and *Prodenia ornithogalli* (Lepidoptera, Phalaenidae) were recovered from the outer surface of planes that arrived at Miami, Florida, from the Caribbean area and South America. It is conceivable that these lepidopterans or related species, transported in the egg stage on the exterior of aircraft, could become established and pose a serious economic threat in areas where they do not presently occur.

[1] Most of the determinations were made by entomologists of the U. S. National Museum, Washington, D. C.

LITERATURE CITED

Buren, W. F. 1948. Viable insect egg mass transported on outside of aircraft. Pub. Health Rep. **63**(43): 1404.

Senior-White, R. A. and T. W. Kirkpatrick. 1949. Transport of insects on the exterior of an aircraft. Nature **164**(4158): 60–61.

Evaluation of Certain Insecticides in Horn Fly Control

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During the past four seasons, 1946–to 1949, several insecticides have been tested to evaluate their efficacy in the control of the horn fly, *Siphona irritans* (L). All tests were made under field conditions, using either dairy or range herds. These herds, selected at five locations in southeastern Wyoming, were representative of most of the elevations in the state where horn flies are a serious problem to livestock. These elevations varied from approximately 4100 feet to 7500 feet. The dairy herds consisted of Holsteins, Guernseys, Ayrshires, and Brown Swiss, while the range herds were all Herefords.

METHODS.—The five geographical areas at which the tests were carried out provided sufficient variety of conditions to allow for proper evaluation of the insecticides. At each location several herds were selected so as to provide a comparable basis for determining length of effective control for each insecticide. At weekly intervals, or as near thereto as possible, hornfly counts were taken on each treated herd. Readings were usually made in the forenoon at approximately the same time of day and only under favorable weather conditions. At all times the horn-fly populations were determined by the same two observers, who made the counts by walking through the herds. Untreated herds in each of the five localities were selected as checks. If at all possible the herd was resprayed when the average horn-fly count reached 25 to 30 flies per animal.

All insecticides were applied to the animals at approximately 150 lb. pressure with a small power sprayer using one nozzle. One to two pints of insecticide was applied to each animal and this was directed only to the topline and underline. At this rate of application there was a minimum of runoff or waste of material, but sufficient spray was applied to both top and underline.

DENSITY OF HORN-FLY POPULATIONS.—Horn flies are present on dairy and range cattle in Wyoming during a period of 7 months—generally from the latter part of April to late October. Actual dates of observed occurrences in southeastern Wyoming are from April 23 to October 29. In April, the fore part of May, and most of October the horn-fly population is too low to cause the average dairyman or rancher to begin control. Data accumulated from 1946 through 1949 indicate that at an elevation of 4000 to approximately 6000 feet the significant build-up in horn-fly numbers begins about the middle of July with the peak being reached the latter part of August and the first three weeks of September. Then a rather steep decline takes place which may result in complete absence of horn flies at any time during the last two weeks of October. During the 6 weeks of greatest abundance—the last 3 weeks of August and the first 3 weeks of September—the highest counts on untreated herds will average between an estimated 5000 and 6000 flies with individual animals carrying up to about 10,000.

Because of the varying elevations in Wyoming the seasonal occurrence and density of horn-fly populations exhibits considerable variation. At the Laramie elevation of approximately 7200 feet very few flies are observed before the latter part of May, and practically none are present beyond the first week in Octlober. At this elevation the average numbers have been consistently smaller than at the other locations where tests have been carried out.

RESULTS OF TREATMENT.—A summary of the results of tests conducted during 1946–1949 with different insecticides and varying concentrations is presented in table 1.

It is evident from examination of table 1 that considerable variation may exist in length of effective control obtainable. An increase of six times in concentration of DDT (from 0.25 to 1.50 per cent) resulted only in approximately doubling the length of the satisfactory control period. Similarly, tripling the methoxychlor concentration (0.5 to 1.5 per cent) lengthened horn-fly protection by about 50 per cent.

The average effective control period obtained in Wyoming was not as long as that reported for comparable treatments in the Midwest or South (Bruce & Blakeslee 1948, Cuff 1948,[1] and McGregor 1949). More intensive sunlight and generally windy conditions may offer an explanation for the shorter

[1] Presented at the meeting of the Texas Entomological Society, Houston, Texas, January 19–20, 1950.

Table 1.—Control of horn flies on cattle sprayed with different insecticides and varying concentrations.

Number of Tests	Concentration of Insecticide	Days Protection[1]	
		Average	Range
7	0.25% DDT W. P.[2]	14.6	7–21
2	0.5% DDT W. P.	16	16
18	1.5% DDT W. P.	27.2	10–42
5	2.5% DDT W. P.	33	25–48
4	1.5% Dichlorodiphenyl dichloroethane W. P.[3]	21.7	12–35
4	0.5% Chlordane W. P.[4]	14.5	10–18
3	1.5% Chlordane W. P.	20.6	16–24
8	0.5% Methoxychlor W. P.[5]	18	10–55
8	1.0% Methoxychlor W. P.	22.5	10–35
15	1.5% Methoxychlor W. P.	26.6	10–42
2	DDT-Benzene hexachloride W. P.[6] 38.1% DDT 2.3% Gamma isomer of Benzene hexachloride 12.2% Other isomers of BHC 47.4% inert	21	21
6	Pyrenone 40–2 emulsion[7] 1.00% Piperonyl butoxide 0.05% Pyrethrins	12.6	7–21
2	Pyrenone 10–05 emulsion 1.00% Piperonyl butoxide 0.05% Pyrethrins	10.5	7–14
4	Pyrenone wettable powder 1.00% Piperonyl butoxide 0.075% Pyrethrins	14.2	9–21

[1] Period when an average of less than 25 to 30 horn flies per animal were present.
[2] DDT furnished by Dow Chemical Company and E. I. du Pont de Nemours & Company, Inc.
[3] DDD furnished by Rohm & Haas Company.
[4] Chlordane furnished by Julius Hyman & Company and Velsicol Corporation.
[5] Methoxychlor furnished by E. I. du Pont de Nemours & Company, Inc.
[6] DDT-BHC W. P. furnished by E. I. du Pont de Nemours & Company, Inc.
[7] The pyrethrum-piperonyl butoxide combinations were furnished by the U. S. Industrial Chemicals, Inc.

effective period of residual action of the newer insecticides in Wyoming. Under Wyoming conditions four to five applications a season were found to be required to keep horn flies at a low level (less than an average of 25 flies per animal). An attempt was made to determine whether or not an early insecticidal spray application would result in a decrease in the total number of treatments required during the fly season. Four herds were selected, two at an elevation of 4200 feet and two at 7200 feet. All herds were sprayed in May when few flies were present (only 1 fly observed in one herd and an average of 60 in another herd treated with .5 per cent methoxychlor; 5 flies observed in one herd and an average of 18 in another herd treated with 1.0 per cent methoxychlor). The initial application resulted in effective protection for a period of 23 to 55 days with .5 per cent methoxychlor and 22 to 33 days with 1.0 per cent methoxychlor. However, the total number of treatments necessary for satisfactory protection during the season was again four to five.

SUMMARY.—Satisfactory protection of cattle from horn flies was obtained with all insecticides tested, namely, DDT, methoxychlor, DDT-benzene-hexachloride mixture, dichlorodiphenyl dichloroethane, chlordane, and pyrethrins-piperonyl butoxide combinations. The insecticidal sprays were applied to the top and underlines at a pressure of approximately 150 pounds per square inch and at a rate of 1 to 2 pints per head.

In conformity with the recommendations of the Food and Drug Administration and the Bureau of Entomology and Plant Quarantine (1949), it was found that a safe and satisfactory insecticide for dairy herds would be a 1.0 per cent methoxychlor wettable powder. Proper concentrations of pyrethrins-piperonyl butoxide wettable powder sprays are also safe and effective, but they would have to be applied more often. Satisfactory control of horn flies on range herds may be obtained with a 1.5 per cent DDT wettable powder spray. Under Wyoming conditions it appears that a minimum of four or five treatments are required to provide adequate control, each treatment with DDT or methoxychlor providing about 3 or 4 weeks of protection.

LITERATURE CITED

Anon. 1949. The new insecticides for controlling external parasites of livestock. U. S. Dept. Agr., Bur. Ent. and P. Q. **E-762** (Revised).

Bruce, W. G., and Blakeslee, E. B. 1948. Factors affecting tests with DDT sprays to control horn flies. JOUR. ECON. ENT. **41**(1): 39–42.

McGregor, W. G. 1949. Field tests of insecticides and spraying methods to control horn flies in dairy herds. JOUR. ECON. ENT. **42**(4): 641–3.

An Improved Laboratory Method for Testing Materials as Screw-Worm Larvicides[1]

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A culture medium for rearing larvae of the screw-worm, *Callitroga americana* (C. & P.), was developed by Melvin & Bushland (1936). A modification of this medium was utilized by Bushland (2) in testing several hundred organic compounds against newly hatched screw-worm larvae. It contained the following ingredients: Ground lean meat 50 grams, citrated beef blood 25 cc., water 75 cc., and formalin 0.3 cc. The candidate insecticide was mechanically mixed with the meat, which was then added to a mixture of the blood, water, and formalin. His initial tests were made with 1 gram of the test material in 150 grams of the medium.

During 1947 the authors made some changes in this method which have expedited the screening of screw-worm larvicides by reducing the quantity of test material used and by saving labor. Several hundred compounds, many of which were very rare and not available in 1-gram quantities, have been tested by this method during the last 3 years.

MEDIUM FOR LARVAE.—The medium in which the larvae are reared and tested is given as follows: Citrated beef blood 15 per cent, water 44.7 per cent, ground lean meat 40 per cent, and formalin (37 per cent formaldehyde) 0.3 percent.

TEST PROCEDURE.—A 5 per cent solution of the

[1] Printed sheet issued by the Livestock Exchange, Kansas City, Mo.

candidate insecticide is prepared by dissolving it in a mixture containing 9 parts of acetone and 1 part of a polyoxyalkylene derivative of sorbitan monolaurate.[1] Six ml. of the blood-water-formalin mixture is pipetted into a 30-ml. beaker, followed by 0.2 ml. of the insecticide solution. This mixture is thoroughly stirred with a glass rod, and then 4 grams of the ground lean meat is added. The medium is stirred again and warmed at 90° F. for about an hour before the larvae are added.

Initial tests of candidate compounds are made at 0.1 per-cent concentration. The addition of 0.2 ml. of a 5-per-cent solution in 10 grams of medium gives this concentration.

About 25 larvae are used per test. Materials that do not kill all the larvae in 48 hours are not tested further. Materials that cause complete mortality are retested at lower concentrations until the minimum lethal concentration is determined. The tests are conducted at 90° F. and a relative humidity of approximately 85 per cent.

The wetting agent[1] is used to help prevent precipitation and to obtain a more uniform distribution of the chemical in the medium. It is nontoxic to the larvae at the concentration used. Newly hatched larvae will tolerate up to approximately 4 per-cent of acetone without noticeable injury. As much as 10 per cent of acetone can be added to the medium if it is allowed to stand overnight. Both benzene and chloroform were tried as solvents in place of acetone but proved less satisfactory.

TOXICITY OF MATERIALS TESTED BY THE NEW TECHNIQUE.—Several unrelated compounds were tested by this method in direct comparison with the method used by Bushland (1940). In general, the materials proved more toxic by the new method and in no case did they prove less toxic. A more uniform distribution of the chemical in the media, along with a reduction in particle size, probably accounts for much of this increased toxicity.

ADVANTAGES OF THE NEW METHOD.—Perhaps the main advantage of this method lies in the fact that it permits the testing of a greater number of materials. The method is not only more rapid but is probably more accurate. Only 10 grams of the medium is required for each test as compared with 150 grams by the original method. Only 100 mg. of insecticide is needed for the initial tests as compared with 1 gram by the other method.

LITERATURE CITED

Melvin, R., and R. C. Bushland. 1936. A method for rearing *Cochliomyia americana* C. & P. on artificial media. U. S. Bur. Ent. and Plant Quar. **ET-88.**

Bushland, R. C. 1940. The toxicity of phenothiazine and certain related compounds to young screw-worms. JOUR. ECON. ENT. **33**(4): 666–9.

Effect of Temperature on Toxicity of Certain Organic Insecticides[1]

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The effect of temperature on the toxicity of a number of insecticides has been reported by previous workers. A brief summary of these papers indicates two general trends of the effect of temperature on toxicity. One is an increase in toxicity at the lower temperatures, and the other an increase in toxicity at the higher temperatures. Compounds fitting into the first category include pyrethrum (Chevalier 1930, and numerous others), DDT (Lindquist *et al.* 1945, Hoffman & Lindquist 1949, Hoffman *et al.* 1949, Fan *et al.* 1948), DDD and methoxychlor (Hoffman & Lindquist 1949, Hoffman *et al.* 1949), rotenone (Klinger 1936), lethane (Eagleson 1942), lauryl thiocyanate, nocotine, and DNOC (Potter & Gillham 1946), arsenic and fluoride compounds (Ellisor & Blair 1940). Those compounds most toxic at the higher temperatures include lindane, chlordane, aldrin, dieldrin, heptachlor, toxaphene, and parathion (Hoffman *et al.* 1949, Hoffman & Lindquist 1949). The purpose of this paper is to establish the effect of temperature on the toxicity of five organic insecticides applied topically to the German cockroach, *Blatta germanica* L.

MATERIALS AND METHODS.—Adult female roaches were isolated from the stock culture and prepared for treatment by being placed in battery jars provided with food and water, and acclimated for 24 hours in a constant temperature chamber at the specific temperature at which they were to be tested.

The acclimated roaches were removed from the temperature chamber in lots of approximately 100 each as they were being treated. By following this procedure the roaches were exposed to room temperature for only a matter of 15 minutes or less, and were returned to the temperature chamber immediately after treatment. The toxicants were applied to the sternum of the roaches in a manner similar to the one described by Kearns *et al.* (1945). After treatment the roaches were placed in Kerr mason jars provided with food and water, and replaced in the temperature chamber.

Twenty-five roaches were used for each test and tests were replicated two or more times so that at least 50 insects were used at each concentration for each different temperature except in a few instances where only one test was made.

The LD-50 values of the compounds at each separate temperature were determined with the aid of a dosage mortality curve according to the method described by Finney (1947). The standard deviation and fiducial limits were also established in accordance with this method.

The treated roaches were subjected to one of three temperatures for a period of five days. The temperature was regulated to 14.5° C, 22° C, and 32° C. with a variation of plus or minus 1.5° C. in each case. The relative humidity varied between 75 and 85 per cent.

Every 24 hours for a period of 5 days the treated roaches were removed from the temperature chamber and the number of roaches dead or moribund was determined. Roaches were removed, counted, and replaced in the chamber as quickly as possible, in no case exceeding 10 minutes.

All toxicants used were essentially pure compounds except pyrethrum which was diluted from a 20 per cent concentrate.

RESULTS AND DISCUSSION.—The results of all tests are summarized in table 1.

The results shown in table 1 indicate that DDT, pyrethrum, and lindane were more toxic at the lower temperatures while the reverse was true with aldrin and dieldrin. It should be pointed out that results with lindane were quite variable although the general trend was maintained throughout.

[1] Contribution from the Entomological Laboratories of the University of Illinois.

[2] Research Assistant.

Table 1.—Effect of temperature on the LD-50 (micrograms/roach) of some organic insecticides applied topically to adult female German roaches.

Compound	Degrees Centigrade		
	32	22	14.5
DDT	40.8 ±2.2	12.9 ±2.2	2.1 ±0.31
Pyrethrins	1.45±0.23	0.8 ±0.23	0.32 ±0.23
Lindane	0.18±0.02	0.10±0.02	0.071±0.02
Aldrin	0.4 ±0.22	0.57±0.22	1.36 ±0.22
Dieldrin	0.22±0.02	0.35±0.02	1.1 ±0.02
Ck. (1 cm dioxane)	3.5% mortality	1% mortality	1% mortality

Temperature had the greatest effect on the toxicity of DDT which was about 20 times more effective at the lower temperature. The effect of temperature on the toxicity of the other compounds was considerably less. Pyrethrum and dieldrin were about 5 times as effective at one extreme as at the other, and lindane and aldrin were about 3 times as effective at one extreme as at the other.

SUMMARY.—The effect of temperature on the toxicity of five organic insecticides applied topically to the German cockroach has been determined. DDT, pyrethrum, and lindane gave better results at the lower temperatures and dieldrin and aldrin gave better results at the higher temperatures.

LITERATURE CITED

Chevalier, J. 1930. Le pyrèthre (Chrysanthème insecticide). Activité pharmacodynamique et thérapeutique. Bul. Sci. Pharmacol. **37:** 154–56.

Eagleson, C. 1942. The effect of temperature on the recovery of houseflies. Soap **18:** 115, 141.

Ellisor, L. O. and C. R. Blair. 1940. Effect of temperature upon the toxicity of stomach poisons. JOUR. ECON. ENT. **33:** 760–2.

Fan, H. Y., T. H. Cheng, and A. G. Richards. 1948. The temperature coefficients of DDT action in insects. Phys. Zoo. **21:** 48–59.

Finney, D. J. 1947. Probit analysis. University Press, Cambridge, England.

Hoffman, R. A. and A. W. Lindquist. 1949. Effect of temperature on knockdown and mortality of house flies exposed to residues of several chlorinated hydrocarbon insecticides. JOUR. ECON. ENT. **42:** 891–93.

Hoffman, R. A., A. R. Roth, and A. W. Lindquist. 1949. Effect of air temperature on the insecticidal action of some compounds on the sheep tick and on migration of sheep tick on the animal. JOUR. ECON. ENT. **42:** 893–96.

Kearns, C. W., L. Ingle, and R. L. Metcalf. 1945. A new chlorinated hydrocarbon insecticide. JOUR. ECON. ENT. **38:** 661–68.

Klinger, von. H. 1936. Die insektizide Wirkung von Pyrethrym- und Derrisgifter und ihre Abhangigheit vom Insektenkorper. Arb. phys. angew. Ent. **3:** 49, 115.

Lindquist, A. W., H. G. Wilson, H. O. Schroeder, and A. H. Madden. 1945. Effect of temperature on knockdown and kill of houseflies exposed to DDT. JOUR. ECON. ENT. **38:** 261–64.

Potter, C. and E. M. Gillham. 1946. Effects of atmospheric environment, before and after treatment, on the toxicity to insects of contact poisons. I. Ann. App. Biol. **33:** 142–59.

Preliminary Evaluation of Two Nitroparaffin Insecticides Against Four Cotton Insects[1]

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Two new nitroparaffin insecticides were made available for research on the control of cotton insects during 1949. These materials were designated by the manufacturer as CS-645A and CS-674A, corresponding to the chemicals 2-nitro-1,1-bis (*p*-chlorophenyl) propane and 2-nitro-1,1-bis (*p*-chlorophenyl) butane, respectively. They were supplied as dust concentrates reported to contain 50 per cent of the active ingredient.

Cage toxicity tests with these insecticides were conducted at College Station, Texas, against adults of the boll weevil, *Anthonomus grandis* Boh., third instars of the bollworm, *Heliothis armigera* (Hbn.), and the cotton leafworm, *Alabama argillacea* (Hbn.), and third and fourth instars of the salt-marsh caterpillar, *Estigmene acrea* (Drury). All insects were reared in the laboratory.

The standard procedure used in field-cage experiments was followed in evaluating these insecticides against the boll weevil and the bollworm. In the tests against the cotton leafworm and the salt-marsh caterpillar, owing to the lateness of the season, the cages were placed in the greenhouse instead of the field and cut branches of field-grown plants were used in the place of growing plants. The stems of the cut branches were kept immersed in water throughout the tests, thereby making conditions favorable for accurate evaluation of the toxicant.

All treatments were applied as dusts, which were

Table 1.—Toxicity of the nitroparaffin insecticides CS-645A and CS-674A tested against four species of cotton insects, College Station, Texas, 1949.

Dust Treatments	Average Mortality After 5 Days			
	Boll Weevil	Boll-worm	Cotton Leaf-worm	Salt-Marsh Caterpillar
CS-645A 2.5% plus CS-674A 5%	31	36	—	91
5% plus CS-674A 10%	69	91	—	100
10% plus CS-674A 20%	80	94	—	100
2.5%	32	35	—	—
5%	48	29	56	—
10%	59	32	80	—
20%	—	—	92	37
CS-674A 5%	53	55	97	96
10%	70	85	100	100
20%	78	92	100	100
Toxaphene 20%	99	88	98	50

[1] Report of a study made under the Research and Marketing Act of 1946, in cooperation with the Texas Agricultural Experiment Station.

[2] Presented at the meeting of the Texas Entomological Society at Houston, Texas, January 19–20, 1950.

formulated from the dust concentrates by ball-milling them with pyrophyllite for 15 minutes. A 20 per cent toxaphene dust was included in each test as a standard of comparison. Untreated check cages were likewise included and the average mortality was calculated by Abbott's formula. For tests against the boll weevil and the bollworm there were three cages for each treatment in each replicate, and for tests against the cotton leafworm and the salt-marsh caterpillar there were two cages. There were five replicates except in tests against the salt-marsh caterpillar when there were three. The dusts were applied at the rate of 10 pounds per acre against all the insects except the salt-marsh caterpillar, against which 15 pounds were applied. Mortality counts were made twice daily for 5 days.

RESULTS.—The results of these tests are summarized in table 1. These data show that in most tests no appreciable advantage was gained by combining the compounds CS-645A and CS-674A in the ratios tested. However, all three combinations were more effective than 20 per cent CS-645A or 20 per cent toxaphene against the salt-marsh caterpillar, possibly because of the presence of CS-674A, which was very effective against this insect. Compound CS-654A was generally much less effective than compound CS-674A. At the rates tested against the boll weevil neither compound compared favorably with 20 per cent toxaphene. Compound CS-674A at concentrations as low as 10 per cent against the bollworm and 5 per cent against the cotton leafworm compared favorably with 20 per cent toxaphene against both insects. However against the salt-marsh caterpillar CS-674A was almost twice as effective as 20 per cent toxaphene at the end of 5 days.

Toxicity of Dinitro Ortho Secondary Amyl Phenol[1] to the Two-Spotted Spider Mite on Strawberry Plants

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Trials involving the use of chemicals for the control of such winter weeds as chickweed, *Stellaria media*, and henbit, *Lamium amplexicaule*, in strawberry fields have been in progress at this station since 1945. Results have indicated that spray applications of 75 per cent dinitro ortho secondary amyl phenol in combination with kerosene or diesel fuel and water may prove to be a very practical means of control. In addition to these weed controlling effects, it was also observed in the course of the 1948–49 trials that strawberry plants treated with this chemical were virtually free of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, whereas adjacent untreated areas had large populations of this insect (Danielson 1949). Examination of a number of widely separated commercial fields treated with this material gave further evidence to support the observations made on the trial plots during that season. These observations formed the basis for a detailed field study of this toxic effect in the winter of 1949–50. This study has demonstrated the effectiveness of herbicidal concentrations of dinitro ortho secondary amyl phenol as a practical means of control for two spotted spider mites in strawberry plantings. The results are presented here.

Table 1.—Results of treating Blakemore strawberries with dinitro ortho secondary amyl phenol for two spotted spider mite control. Spray solution used in all trials—1 quart 75 per cent dinitro ortho secondary amyl phenol, 6.5 gallons kerosene, water to make 100 gallons.

A. Non-Replicated Preliminary Tests (Treated 12/19/49)

Gals. Spray per Acre	Mites per 20 (0.3 Sq. In.) Leaf Samples[1]			
	1/4/50		1/23/50	
	No. Alive	Per Cent Reduction	No. Alive	Per Cent Reduction
25	38	81.0	25	91.3
50	28	86.0	10	96.5
100	4	98.0	8	97.2
0	200	—	289	—

B. Replicated Preliminary Tests (Treated 1/23/50)

Gals. Spray per Acre	Mean No. Mites per 50 (0.3 Sq. In.) Samples[1]					
	1/25/50			1/27/50		
	Alive	Dead	Per Cent Dead	Alive	Dead	Per Cent Dead
25	138.0	1377.3	90.9	44.0	1405.7	97.0
50	10.3	1451.3	99.3	7.0	1368.0	99.5
100	4.7	1443.0	99.7	2.0	1441.3	99.9
0	1404.3	92.0	6.1	1380.0	90.7	6.2

C. Replicated Tests Using Field Power Spray Equipment (Treated 2/1/50)

Gals. Spray per Acre	Mean No. Mites per 100 (0.3 Sq. In.) Samples[1]					
	2/3/50			2/6/50		
	Alive	Dead	Per Cent Dead	Alive	Dead	Per Cent Dead
25	47.0	2774.7	98.3	13.7	2348.7	99.4
50	25.3	2533.3	99.0	14.3	2470.0	99.4
100	2.3	2882.7	99.9	0.3	2413.0	99.9
0	2624.0	424.0	13.9	2554.0	689.7	18.8

[1] Population counts in all experiments made by selecting a heavily infested area on each leaf and extracting a 0.3 sq. in. leaf plug by means of a cork borer.

Preliminary tests consisting of non-replicated plots of 0.01 acre treated with a knapsack type sprayer operating in a pressure range of 30 to 50 pounds per square inch were conducted for the purpose of evolving a satisfactory method of making *T. bimaculatus* mortality determinations. Results of a representative series of these preliminary tests are given in Table 1A. An increase in mortality with increase in rate of application and elapsed time between treatment and evaluation was observed. The method of evaluation presented here appeared satisfactory for the purposes of these trials.

These effects were further tested in a series of replicated small plots using the same treatments and methods of application as in preceding preliminary tests. Results obtained on these plots which were replicated 3 times are given in Table 1B. These showed the same encouraging trends as were seen in the previous trials and the method of determining relative spider mortalities proved highly satisfactory from a statistical viewpoint.

[1] *Sinox* General—Standard Agricultural Chemicals, Inc.
[2] Associate Entomologist.
[3] Plant Physiologist.

Results of these preliminary trials were so promising that a series of field operation type plots were organized to test the practicality of the method and to obtain further comprehensive data. Large scale, replicated field plots were sprayed at a pressure of 250 pounds per square inch using a John Bean Model 404T sprayer equipped with fan type nozzles. Plots were 0.25 acre in size and were replicated 3 times. Rates of application were the same as those used in the preliminary hand treated plots Variations in rates were obtained by allowing the pump pressure to remain constant and varying the rate of movement of the sprayer. Results of this final series of trials are reported in Table 1C and offer conclusive evidence that 75 per cent dinitro ortho secondary amyl phenol in herbicidal concentrations effectively controlled the two-spotted spider mite in Blakemore strawberries under weather conditions prevailing in this area in the winter of 1949–50.

LITERATURE CITED

Danielson, L. L. 1949. Winter weed control in Blakemore strawberries. Va. Truck Expt. Sta. Veg. Growers News **4**(3): 3.

Relative Toxicity to House Flies of Tetra-n-Propyl Dithionopyrophosphate

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A pure, laboratory-prepared sample of tetra-n-propyl dithionopyrophosphate, when received from a chemical manufacturer, was accompanied by the statement that the compound had been found to be nontoxic to white mice. This would be of great interest in the insecticide field, if at the same time the compound was toxic to insects, because of the high toxicity of organic phosphorus insecticides not only to insects but also to warm-blooded animals including man. Pending the publication of pharmacological data dealing with this important question, it was thought of value to determine the relative toxicity to an insect of the compound in oil sprays.

Determination was made by the turntable method on adult house flies, *Musca domestica* L., reared by standard laboratory procedure. Sprays were prepared in deodorized kerosene at concentrations selected in accordance with the results of preliminary tests. Mortality percentages were determined in nine replications at each concentration, approximately 100 flies being used in each test. Tests were also made with the mixture of "pyrethrins" obtained from pyrethrum flowers, the usual standard of comparison for fly sprays, and with parathion, because of its chemical relationship and high toxicity to house flies. The parathion was a pure crystalline compound, this being especially emphasized because in a comparative study previously reported (Gersdorff & Nelson 1948) a sample of technical-grade material had been used.

The results of these tests are given in table 1. To determine the concentrations causing 50 per cent mortality, the results were plotted on log-probability paper and these values obtained from the straight lines fitted by the method of least squares.

Table 1.—Relative toxicity to house flies of parathion, tetra-n-propyl dithionopyrophosphate, and pyrethrins in oil sprays.

MATERIAL	CONCENTRATION	MORTALITY IN 1 DAY	LC 50[1]	RELATIVE TOXICITY
	Mg. per Ml.	*Per Cent*	*Mg. per Ml.*	
Parathion	0.100	81	0.0483	1.0
	.075	77	—	—
	.056	60	—	—
	.042	48	—	—
Tetra-n-propyl dithionopyrophosphate	1.78	72	0.904	0.048
	1.33	61	—	—
	1.00	52	—	—
	0.75	45	—	—
Pyrethrins	7.50	86	3.08	0.014
	3.75	52	—	—
	1.875	24	—	—
	0.938	15	—	—

[1] Concentration causing 50 per cent mortality.

There were pronounced differences in the toxicity of the materials to house flies. At the 50 per cent mortality level tetra-n-propyl dithionopyrophosphate was about one-twentieth as toxic as parathion and yet about three times as toxic as "pyrethrins". These relationships were not greatly different at the other levels of kill, since the curves were practically parallel. Thus the toxicity to house flies of the new phosphate was found to have about the same ratio to that of pure parathion as technical hexaethyl tetraphosphate had to a technical grade of parathion in the previous study.

In comparing the relative toxicity of parathion and "pyrethrins" with the results obtained in this previous study, one must bear in mind, in addition to the difference in purity of the samples of parathion and especially the difference in type of action of the two toxicants, that the carriers used in the sprays were different in the two comparisons. In the previous study, a 1:1 mixture of acetone and deobase was used; in the present one, deobase alone was used. Acetone strongly enhances the effect of pyrethrins on house flies; the degree to which it may enhance the effect of parathion is not known. There is no reason to assume that this is the same for materials of such dissimilar chemical composition.

These results show that, if tetra-n-propyl dithionopyrophosphate is found to be nontoxic or low in toxicity to man, further work with this compound as a potential insecticide is desirable.

LITERATURE CITED

Gersdorff, W. A., and R. H. Nelson. 1948. Toxicity to house flies of three phosphorus acid esters. JOUR. ECON. ENT. **41**(2): 333.

The Development of Resistance to American Foulbrood by Honey Bees in Hawaii

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Phillips (1909) reported that the foulbrood diseases of bees were not known to exist on any of the Hawaiian islands. In 1908, the Board of Commissioners of Agriculture and Forestry of the Territory of Hawaii passed regulations which placed restrictions on the importation of bees and of honey into the Territory to prevent the introduction of infec-

tious diseases. When these regulations were relaxed sufficiently to permit the introduction of American foulbrood is not known to the writer but the disease must have been present in the early thirties when Keck (1937) reported that the apiaries on Oahu were inspected in 1932 and checked again in 1933 and that all diseased colonies were destroyed by burning. There have been no systematic inspections since that time.

The Molokai Ranch, Ltd. operated some 2175 colonies of bees in 1934 and increased this number to 2400 colonies by 1938, from which they produced an average of some 2000 (120 lb.) cases of honey annually. In 1937, 50 per cent of the Molokai Ranch colonies were found to be infected with American foulbrood. The disease was thought to have been brought to the island in the early thirties in used equipment from the island of Maui. The infected colonies were burned in 1937 and the inventory of colonies increased to 2400 colonies in 1938. However, by the end of 1938, 2200 additional colonies were burned and beekeeping as a commercial project was practically abandoned, only 246 colonies being listed on the 1939 inventory.

The colonies were neglected and much of the equipment was scattered throughout the island during the next 10 years. Several thousand supers and frames were salvaged, however, and were steam cleaned and stored in several warehouses. The surviving colonies numbered about 240 hives through 1941, but had dwindled to less than 100 at the time it was decided to revive the industry in 1949.

When the Molokai Ranch colonies were first inspected in the spring of 1949, 13 colonies were found to be diseased out of 86 inspected. In early summer the colonies became honey bound and swarms were hanging in the trees when an apiarist was put in charge. It was then noted that some of the colonies which had been marked as diseased earlier, were apparently free of disease and the idea of the development of a natural resistance to the disease was raised. During the remainder of the year, when the colonies were being increased and equipment readied for use, hundreds of hives were brought in from abandoned apiaries, their combs largely destroyed by the greater wax moth. Some colonies had persisted, either in spite of neglect or as a result of stray swarms. No additional cases of disease were found in any of the colonies. Numerous swarms were observed in the cliffs, in stacks of rolled tar paper, and in trees. These swarms were examined and removed wherever possible. In no instance were these colonies found infected with American foulbrood. One hundred and sixty one swarms were captured in decoy hives by July in 1950 and none of these showed any evidence of the disease.

A careful survey of the beekeeping situation on Molokai, made by the writer and Mr. Luce in October of 1949, turned up but one light case of American foulbrood in the Molokai Ranch bees. An abandoned apiary, consisting originally, in 1946, of some 35 two-story colonies, was found to contain 12 colonies infected with American foulbrood, 25 hives in which the colonies had died and most of their combs destroyed, and 27 undiseased colonies. The colonies had been divided in 1946 at which time queens from the mainland had been introduced into the divides. They apparently had not been examined since that date as the queen cages were still in place. An examination of the same apiary was made in May of 1950 by Mr. Luce who found 19 colonies still alive, of which four were infected with American foulbrood. It was apparent that most of the previously diseased colonies had died out and their combs had been destroyed by the wax moth. Two of the four diseased colonies were new infections.

TESTS TO INDICATE THE PRESENCE OF THE RESISTANT FACTOR.—In a small apiary near Kaunakakai, two colonies were selected in September, 1949, to test their apparent resistance to American foulbrood. Four supers of combs containing American foulbrood scales, dead larvae and pupae were placed above a queen excluder on Colony A and one frame containing numerous cells of diseased brood was placed in the center of Colony B with the following results:

Colony A. October 7. The four supers of combs were removed and one comb containing many cells of diseased brood was inserted in the center of the brood chamber. No disease was observed below the queen excluder.

October 15. Six cells of AFB were found in three combs.

October 20. Eighteen cells of disease were found in four combs.

October 29. Twenty-nine cells of disease were found, none being in the inserted comb.

November 9. Only three cells of disease were found; healthy brood in the inserted comb.

November 26. One cell of AFB.

December 12. No disease was apparent.

1950—No disease has been evident at any time.

Colony B. No evidence of disease was found in this colony on frequent examinations during 1949 and 1950.

RESISTANT TESTS MADE AT DAVIS, CALIFORNIA.—The writer selected 12 queens at random from the Molokai Ranch colonies and brought them back to Davis for tests under California conditions. Of this number, only six survived the trip, introduction, and winter period. After the six remaining colonies had built up to swarming strength in the spring of 1950, they were placed on combs with two of their frames of brood, and were each given a comb containing hundreds of scales of American foulbrood. Table 1 shows the results of observations made during April, May, and June of 1950. Observations are being continued.

From these results it is apparent that the Molokai strain of bees has a resistant factor of significant value in the control of American foulbrood. The fact that the abandoned apiary near Kaunakakai, consisting largely of an Italian strain of bees from the mainland, is being decimated by the disease, lends evidence to the fact that environmental factors are not deciding influences in the prevalence of virulence of the disease on Molokai.

CONTRIBUTING FACTORS OF VALUE.—While surveying the beekeeping conditions on Molokai, it became apparent to the writer that natural conditions may have some value in the control of American foulbrood if the Molokai strain of bees was developing the factor of resistance. Conditions are ideal for the development of the greater wax moth, and it was present in every hive in which the colony strength was not sufficient to cover every comb. No parasites of the wax moth were found at any time. *Nosema apis* was present in many colonies on Oahu and Molokai, and this parasite may be a factor in aiding the wax moth in its destruction of combs during the winter and spring periods. Phillips (1907) indicated that wax moth larvae do not destroy the scales of American foulbrood and so do not remove the source of infection from a hive even

though they do destroy the combs. Their webs and the frass of the larvae make the possibility of the spread of the disease through robbing less than if the combs were left intact. The prevalence of the wax moth on Molokai results in the destruction of the brood combs as fast as they are uncovered by the dwindling strength of any weakened colony and usually before the combs are exposed to robbers.

Another factor which might aid in the reduction of the spread of disease through robbing is that the major source of honey is from the kiawe, a legume tree, which is a closed relative of the mesquite of California, Arizona, and Texas. This honey granulates solidly within 3 weeks, more or less, after it is stored in the comb. The wax moth larvae have difficulty in getting through it, and robber bees are less

thiazole per gallon of honey or of honey sirup. While this feeding of sulfathiazole as a precautionary measure could becloud the issue of resistance, it could have had no effect on the swarms which came from the cliffs, trees and buildings.

SUMMARY.—American foulbrood seems to have been introduced on the island of Molokai in the early thirties and resulted in the destruction, by fire as well as by direct causes, of more than 3500 colonies in 1937 and 1938. From that time, the remaining colonies were left largely to their own devices until 1949 when an effort was started to revive the once prosperous industry. The disease was found in a small percentage of the colonies still alive in the spring of 1949 but disappeared and has not become evident in 1950, except in a deserted apiary which

Table 1.—The results of artificially infecting six colonies of Molokai strain of bees at Davis, California.[1]

	Colony 46		52		54		55		58		59	
Date	Frames of Brood	Cells of AFB	Frames of Brood	Cells of AFB	Frames of Brood	Cells of AFB	Frames of Brood	Cells of AFB	Frames of Brood	Cells of AFB	Frames of Brood	Cells of AFB
Apr.												
12	5	Insert	5	Insert	—	Insert	—	—	5	Insert	5	Insert
17	5	0	7	Insert	4	Insert	—	—	6	Insert	5	0
27	9	1 cell	9	few cell in 3 fr.	4	Insert	7	0	7	0	6	0
May												
5	7	0	9	100 in 5[2]	6	Insert	7	6 cells in 4 fr.	8	0	6	3 in 1 fr.
10	7	0	—	[2]	7	Insert	—	—	8	0	7	0
13	8	0	8	1, 3, 20, 7 in 4 fr.	8	3 in 1 insert	8	9 in 2 fr.	9	0	7	1 in insert
21	10	2 in 2	9	12, 1, 1,[2] in 3 fr.	8	3, 2 in 2 fr.	8	1 cell	9	0	7	0
26	9	0	8	4, 1, 2, 1[2] in 4 fr.	8	2, 8, 5, 3 in 4 fr. insert	8	5 in 2 fr.	9	0	0	0
June												
2	10	0	15	0[2]	8	3, 2, 5 in 3 fr.	8	7 in 3 fr.	9	3 in 1 fr.	8	0
13	9	0	14	1	8	2 in 1 fr.	8	1 cell	9	0	8	0
20	9	0	12	0	7	0	8	7 in 2, 3 fr.	8	0	7	0

[1] Supers were added to each colony on May 28, above queen excluders.
[2] Fed 0.5 gram of sodium sulfathiazole in honey sirup.

attracted to it than to honey in the liquid state. As a result, one finds the brood combs in a diseased hive generally destroyed by the wax moth before the robber bees begin the slow removal of the granulated honey from the combs around the brood area. The quick granulation of the honey also makes it necessary for the surplus honey to be extracted as such frequent intervals as to preclude the use of more than two or three-story hives for honey production.

The isolation of the island as well as the fact that a vast majority of the colonies were owned by the Molokai Ranch has aided in the development of resistance among the Molokai strain of bees. Their inventory indicates that they imported but one small lot of queens during the past 20 years, permitting their colonies, as well as the numerous escaped swarms, to inbreed. The present strain appears to be a cross between a black bee and the Italian race and is well adapted to island conditions. The swarming instinct is more evident among the six colonies of the Molokai strain at Davis than any we have in our other experimental colonies.

As a precautionary measure against the development of American foulbrood in the colonies established in 1949 and 1950, all honey fed back to the colonies on Molokai for winter feed or to supply spring stores, contained 0.5 gram of sodium sulfa-

consisted largely of a strain of bees recently introduced from the mainland. No disease has been found in stray swarms taken from natural places on the island or from decoy hives. Colonies which were artificially infected with American foulbrood on Molokai and at Davis, California, have shown a marked degree of resistance to the disease. While the number of colonies tested for the resistance factor has been small, the results appear to have a definite significance in the control of the disease. Certain environmental conditions, such as the wax moth, the presence of *Nosema apis* and the quick granulation of the honey from the major floral source may aid in the natural control of American foulbrood on the island of Molokai.

Literature Cited

Phillips, E. F. 1909. A brief survey of Hawaiian beekeeping. U.S.D.A. Bul. 75, Part V.

Keck, C. B. 1937. Observations on beekeeping in Hawaii. Proc. Haw. Ent. Soc. IX (3): 461–7.

Phillips, E. F. 1907. Wax moths and American Foulbrood. U.S.D.A. Bul. 75(II).

An Effective Ant Bait Formula

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The thallium sulphate ant bait formula as published by Back (1937), and in Metcalf and Flint's text (1939) was found to be quite ineffective in eliminating an infestation of the Pharaoh ant, *Monomorium pharaonis* (L.), from a large building on the campus. The infestation throughout the five story structure caused considerable damage to living insect cultures, museum specimens and often the occupants' lunches.

The following modified formula was very effective in eliminating the infestation:

Thallium sulphate	5.5 grams
Extracted honey	3 ounces
Granulated sugar	1 pound
Water	1 pint
Benzoate of soda	0.5 gram

Mix the sugar, honey and benzoate of soda with the water and heat to almost boiling. Then add the thallium sulphate and stir until all is in solution and allow to cool. This preparation should be made in a chemical hood since the vapors given off are very poisonous. Store in a cool place in bottles labelled "POISON."

The poison baits may be exposed to ants by any of the methods described by Back (1937). However, to be effective for longer periods of time the bait must not dry out. A container that was found to be quite satisfactory in preventing this, consisted of a cardboard pillbox having one or two holes one eighth inch in diameter punched through the side of the lid portion to permit the ants to get to and from the bait. The bottom inside part of the box should be coated with melted paraffine. Only a small amount of bait need be placed in each box but a number of boxes should be used when the infestation is widespread.

A 5 per cent chlordane dust or chlordane emulsion is very effective in eliminating ant populations but these should not be used in some situations such as insect culture rooms. Hence the poison baits still have a place in ant control.

LITERATURE CITED

Back, E. A. 1937. House ants. U. S. Dept. of Agriculture Leaflet No. 147: 7.

Metcalf, C. L. and Flint, W. P. 1939. Destructive and useful insects. McGraw-Hill Co. p. 772.

Empoasca bipunctata Introduced into California

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The leafhopper *Empoasca bipunctata* (Oshanin) has been found to be a common pest of elms in southern California. In North America the species has been reported from European elm at Chestnut Hill, Pennsylvania; Siberian elm at Roosevelt, Utah; and from Chinese elm at Ontario, Canada. It has also been reported on elms in middle Europe, on cotton in Asiatic Russia, and on hemp in Italy (Poos and Wheeler 1943).

Material from southern California was identified by Dr. P. W. Oman of the Division of Insect Identification, United States Department of Agriculture. It is a small green leafhopper with a prominent black dot on each forewing.

In the course of investigations on possible vectors of the virus disease "quick decline" of citrus, in California, *E. bipunctata* was found to be common at West Arcadia, Covina, Azusa, Cucamonga, and Rivera. During 1949 it was caught nine separate times on sticky boards hung in citrus trees in quick-decline areas. An infestation at Redlands was reported by Paul Prescott, Inspector for the San Bernardino Agricultural Commissioner's office. Injury to the trees at Azusa and Redlands was especially noticeable.

In California, *E. bipunctata* appears to be confined to elm as a breeding host plant, although it disperses to many other plants. It is most commonly found on Chinese elm. The insect feeds on the mesophyll tissue, causing a white stippling of the leaf. The usable leaf tissue is reduced, and in heavy infestations there is considerable defoliation. DDT dust was found to be a satisfactory control.—8-4-50.

LITERATURE CITED

Poos, F. W., and Nancy H. Wheeler. 1943. Studies on host plants of the leafhoppers of the genus *Empoasca*. U.S.D.A. Tech. Bul. **850**: 16.

Effect of Initial High Dosages of DDT on the Yields of Peas and Wheat

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In connection with experiments for the control of pea weevil and pea aphid with DDT, studies were made at Genesee, Idaho, on the growth and yield of peas of the varieties Thomas Laxton and Alaska in soil treated with 20, 40, and 80 pounds of DDT per acre.

Young & Gill (1948) reported that treatment of soil with DDT at 100 pounds per acre caused damage to tomatoes, rye, and strawberries. Fleming (1948) reported normal growth of peas in soil treated with 250 pounds of 10 per cent DDT in the top 3 inches. Chapman & Allen (1948) reported that in laboratory tests DDT applied at the rate of 100 pounds per acre to seed-germinating media delayed the germination of corn, beans, and cucumbers; but after the initial delay the treated corn and bean plants grew more rapidly than untreated checks. Cullinan (1949) reported that soil treated with DDT in 1945 was still toxic to some plants in 1947. He also reported that the toxicity to plants varies with different varieties and types of soil.

PROCEDURE.—Separate series of plots were treated with DDT in 1946, 1947, and 1948 prior to the planting of peas. In the series started in 1946 the 80-pound dosage was used. Peas were planted in the spring of 1946, wheat in the fall of that year, and peas again in the spring of 1948 after spading the wheat stubble under to approximate the usual fall plowing.

In the series started in 1947 the 80-pound dosage

[1] In cooperation with the Idaho Agricultural Experiment Station. Published with the approval of the Director of the Idaho Agricultural Experiment Station as Research Paper No. 308.

Table 1.—Yield (ounces) of peas as affected by application of 80 pounds of DDT to Genesee loam soil.

Year of Treatment	Crop	Straw		Peas	
		Untreated	Treated	Untreated	Treated
		Alaska Peas			
1946	1946	89	46[1]	100	52[1]
	1948	79	64[2]	88	77[2]
1947	1947	79	57[1]	92	70[1]
	1948	65	50[1]	72	54[1]
1948	1948	48	46	51	53
		Thomas Laxton Peas			
1946	1946	105	48[1]	82	38[1]
	1948	84	70[1]	70	59[1]
1947	1947	104	71[1]	86	58[1]
	1948	69	53[1]	53	44[2]
1948	1948	52	44	40	37

[1] Significant reduction at the 1-per cent level.
[2] Significant reduction at the 5-per cent level.

of DDT was used and peas were planted in the spring of both 1947 and 1948.

In the series started in 1948 DDT was applied to the soil at the rates of 20, 40, and 80 pounds per acre.

Treatments in each series were applied to plots arranged in six randomized blocks, each containing a treated and an untreated plot of both Thomas Laxton and Alaska peas. Treatments and varieties were randomized in each block. One-row plots 10 feet long were prepared by applying the required quantity of DDT dust mixture evenly over an area 1 foot wide and 10 feet long. Applications were made within a frame to confine the insecticide to the desired area. A 50-per cent DDT concentrate was diluted to 10 per cent concentration with pyrophyllite to insure a more even distribution of the insecticide. Pyrophyllite was applied to the check plots.

After the application of the insecticide, the plots were spaded to a depth of 7 or 8 inches and worked up for planting by running a cultivator through the spaded soil and then raking it.

The tests were conducted on Genesee loam soil having a pH of 6.1 and 3.6 per cent of organic matter, according to the Department of Agricultural Chemistry, University of Idaho.

At harvest time the weight of the peas and the weight of the straw produced were recorded.

RESULTS.—The yields of peas grown in soil receiving 80 pounds of DDT per acre are presented in table 1. For the series started in 1946 the application of DDT to the soil at the rate of 80 pounds per acre reduced the yield of peas and straw significantly. The reduction in the yield of Alaska peas was 48 per cent and in that of Thomas Laxtons 54 per cent. The effect of the DDT on the growth of the plants was apparent through most of the growing season. Figure 1 shows the difference in the appearance of the vines at harvest time. Rex winter wheat, grown on these plots in 1947, was not affected by the presence of DDT (Table 2). However, pea yields on the treated plots were again lower during the 1948 season. Alaska peas produced 12 per cent less on the DDT plots than on the untreated plots and the Thomas Laxtons produced 15 per cent less.

Thomas Laxton Untreated | Thomas Laxton Treated | Alaska Untreated | Alaska Treated

FIG. 1.—Pea vines grown on Genesee loam soil treated with DDT at the rate of 80 pounds per acre and on untreated soil.

The series started in 1947 produced similar results. The yields of Alaska and Thomas Laxton peas were reduced 24 and 32 per cent, respectively, in 1947 and 25 and 18 per cent, respectively, in 1948.

Yields were not reduced significantly by the application of 80 pounds of DDT in the series started in 1948. The results of this experiment are summarized in table 3. A possible reason for this departure from the trend shown during the two previous seasons was that the spring of 1948 was unusually wet and, as a consequence, a dense growth of green weeds 6 to 8 inches tall was turned under when the seed bed was prepared. It seems entirely possible, since the yields of the other two series were reduced by the presence of DDT, that the insecticide was tied up by the presence of the green organic matter in the soil. Weed growth was not present on the 1946 and 1947 series of plots when they were prepared for planting.

Table 2.—Yield (ounces) of winter wheat grown on Genesee loam soil treated with DDT at the rate of 80 pounds per acre.

Peas Preceding Wheat Crop	Straw		Grain	
	Treated	Untreated	Treated	Untreated
Alaska	409	425	183	183
Thomas Laxton	414	406	182	178

Differences between treated and untreated plots not significant.

Table 3.—Yield (ounces) of peas grown on Genesee loam soil treated with different dosages of DDT in 1948.

DDT (Pounds per Acre)	Thomas Laxton		Alaska	
	Straw	Peas	Straw	Peas
80	44	37	46	53
40	52	43	45	41
20	48	37	51	55
0	52	40	48	51

Differences not significant.

CONCLUSION.—These studies demonstrated that 80 pounds of DDT per acre mixed with Genesee loam soil is sufficient to reduce the yields of Thomas Laxton and Alaska peas during the first, second, and third crop seasons after application. Rex winter wheat grown during the second season, however, was not affected. This dosage is far in excess of any concentration of DDT that would accumulate from applications of DDT insecticides for the control of pea insects. The maximum that would be required to control severe infestations of pea insects would be approximately 6 pounds per acre in any one season.

LITERATURE CITED

Chapman, Roy K., and T. C. Allen. 1948. Stimulation and suppression of some vegetable plants by DDT. JOUR. ECON. ENT. **41**(4): 616–23.

Cullinan, E. P. 1949. Some new insecticides—their effect on plants and soils. JOUR. ECON. ENT. **42**(2): 387–91.

Fleming, W. E. 1948. Effect on plants of DDT applied to the soil for the destruction of Japanese beetle larvae. U. S. Bur. Ent. and Plant Quar. E-737 Revised.

Young, H. C., and J. B. Gill. 1948. Soil treatments with DDT to control the white-fringed beetle. U. S. Bur. Ent. and Plant Quar. E-750.

Orius insidiosus, an Enemy of a Spider Mite on Cotton[1]

WILLIAM IGLINSKY, JR., and C. F. RAINWATER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[2]

While field-plot experiments on cotton-insect control were being conducted during the summer of 1948 in the Brazos River bottom, near the Texas A. and M. College, at College Station, it was observed that *Orius insidiosus* (Say) was by far the most important natural enemy of the spider mite *Septanychus* sp.[3] in this area. A review of the literature revealed very little information concerning the life history and habits of *O. insidiosus* on cotton; therefore, a preliminary study was made to obtain additional knowledge of this bug. Barber (1936) considered this species an important natural enemy of the corn earworm, *Heliothis armigera* (Hbn.), and reported on its life history and habits largely in connection with the insects attacking corn. Ewing & Ivy (1943) reported this bug as an important predator of *H. armigera* on cotton, and of the cotton aphid, *Aphis gossypii* Glov.

No systematic attempts have been made to follow *Orius insidiosus* through the winter, but occasional searches for it on several host plants during the winters of 1948–49 and 1949–50 in the vicinity of College Station were unsuccessful, except that in February 1950 it was observed on cotton growing in the greenhouse.

From observations made during October 1948, this bug may winter in the egg stage, but it is more likely to hibernate as a mature, mated female. At that time large numbers of adults were observed on goldenrod, which was blooming profusely. Both males and females were observed. This was the first time males were seen during the year, but they were much less numerous than the females. On several occasions during the summer small groups of 10 to 15 bugs, always females, were collected on cotton. Life-history data presented below indicate a preponderance of females. The fact that only females were observed on cotton, whereas both males and females were observed on goldenrod suggests that the males may prefer to feed on pollen and the females on spider mites or insects. Barber (1936) reported that the species fed on pollen. Incidentally, the goldenrod was heavily infested with thrips. Many of the bugs were seen *in coitu*. Only an occasional immature form was observed on the plants, and as soon as blooming ceased no more bugs could be found. The sexes could usually be differentiated by the unaided eye. The mature females are considerably larger and, in proportion to the body, have somewhat shorter wings than the males. The large mature females observed at this time are believed to be the overwintering forms.

Several hundred specimens of *Orius insidiosus* were brought into the laboratory and placed in glass cages having cloth tops. Cotton seedlings heavily infested with *Septanychus* sp. were placed in the cages as feed for the bugs. Eggs were deposited freely in the cotton seedlings, but no bugs were reared past the third instar. Most of them died while hatching or shortly thereafter. The low humidity in the laboratory was probably responsible for these results.

The eggs are deposited in leaf tissue in a position almost horizontal to the leaf, and in the large veins of the leaf or at the base of the leaf petiole they are deposited at an angle. Preference is shown for the two last-named positions. In all instances a narrow neck protrudes above the leaf surface and contains a distinct waxlike cap.

Many hatching eggs were observed under a binocular microscope. The egg cap generally opens as if it were on a hinge, part of it remaining on the egg chorion. The bug works its way outward, swelling as soon as it has passed through the small aperture. The entire bug is usually free of the egg case within about 10 minutes, but sometimes the caudal tip of the abdomen remains in the egg case for a while before the bug finally extricates itself. When hatching, the entire egg comes out of the leaf tissue, and the eggshell can be seen on the outside, usually attached to the oviposition puncture.

The young nymphs begin to feed on adult mites within a few minutes after hatching. In attacking an adult mite, the bug simply rams its beak into the body of the mite and commences to suck the fluid from it. The red fluid can be seen going into the bug, and in very short order the mite is simply a shriveled mass. More often, however, the young bugs feed on the eggs and quiescent nymphs. The capacity for feeding increases with each instar. The fourth and fifth instars are capable of eating as many adult mites as are the mature bugs.

During the latter part of October 10 mature females of *Orius insidiosus* were collected—the last of those found on goldenrod and brought to the laboratory. They were put in a glass cage having a cloth top and containing small cotton seedlings on which a few *Septanychus* sp. were feeding. The bugs were examined from time to time, but apparently did not feed at all during the 45 days in which they lived. Only 10 eggs were deposited by these adults.

[1] Report of a study made under the Research and Marketing Act of 1946.

[2] In cooperation with the Texas Agricultural Experiment Station.

[3] *Septanychus* sp. is being described by E. A. McGregor (in manuscript).

The temperature during this period was almost constant at 80° F. The mean humidity was 43.6 per cent, the range from 25 to 61 per cent. It is believed that low humidity was responsible for the death of these adult bugs, for they were apparently normal until the humidity in the laboratory began to drop.

Detailed life-history records were obtained on 47 individuals of *Orius insidiosus* under laboratory conditions during July and August 1949. The average numbers of days in the various stages were as follows: Egg stage, 3.3; first instar, 1.9; second instar, 1.9; third instar, 1.2; fourth instar, 1.5; fifth instar, 2.3; and total period from egg to adult, 12.1. Of these 47 individuals, 30 were females and 17 were males. Aluminum paint was used for marking each instar. The mean temperature was 87.2° F., and the mean humidity 48.8 per cent.

Egg deposition records were obtained from only four females of *Orius insidiosus* collected from cotton in the field. As some oviposition had undoubtedly already taken place, probably no records on total egg deposition were obtained. The specimens were placed in individual cages in the laboratory on cotton seedlings growing in nutrient solution. Twenty adults of *Septanychus* sp. were introduced onto the plants each day and daily oviposition records were made. The bugs consumed an average of 16 mites daily, sometimes eating all 20 of them. The average length of time for these four specimens to live after being caged was 7.2 days, ranging from 6 to 9 days; the number of eggs deposited per female ranged from 21 to 36, averaging 26 and the average daily rate of egg deposition per female was 3.6 ranging from 0 to 7.

Literature Cited

Barber, G. W. 1936. *Orius insidiosus* (Say), An important natural enemy of the corn ear worm. U.S.D.A. Tech. Bul. **504.**

Ewing, K. P., and E. E. Ivy. 1943. Some factors influencing bollworm populations and damage. Jour. Econ. Ent. **35**(4): 602–6.

Toxicity of an Herbicide[1] to Red Spider in Strawberry Plantings

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Trials involving the use of chemicals for the control of such winter weeds as chickweed *Stellaria media*, and henbit, *Lamium amplexicaule*, in strawberry fields have been in progress at this station since 1945. Results have indicated that spray applications of 75 per cent dinitro ortho secondary amyl phenol,[1] in combination with kerosene or diesel fuel and water may prove to be a very practical means of control. In addition to these weed controlling effects, it was also observed in the course of the 1948–49 trials that strawberry plants treated with this chemical were virtually free of red spider and adjacent untreated areas had large populations of this insect (Va. Truck Exp. Sta. Vegetable Growers News, Vol. 4, No. 3, Sept. 1949). Examination of a number of widely separated commercial fields treated with this material gave further evidence to support the observations made on the trial plots during that season. These observations formed the basis for a detailed field study of this toxic effect in the winter of 1949–50. This study has demonstrated the effectiveness of herbicidal concentrations of 75% dinitro ortho secondary amyl phenol as a practical means of control for red spider in strawberry plantings and results are presented here.

Table 1.—Results of teating Blakemore strawberries with 75% dinitro ortho secondary amyl phenol for red spider control. Spray solution used in all trials—1 quart 75% dinitro ortho secondary amyl phenol, 6.5 gallons kerosene, water to make 100 gallons.

A.—Non-Replicated Preliminary Tests (Treated 12/19/49)

Gals. Spray per Acre	Red Spiders per 20 (0.3 Sq. In.) Leaf Samples[1]			
	1/4/50		1/23/50	
	No. Alive	% Reduction	No. Alive	% Reduction
25	38	81.0	25	91.3
50	28	86.0	10	96.5
100	4	98.0	8	97.2
0	200	—	289	—

B.—Replicated Preliminary Tests (Treated 1/23/50)

Gals. Spray per Acre	Mean No. Red Spiders per 50 (0.3 Sq. In.) Samples[1]					
	1/25/50			1/27/50		
	Alive	Dead	% Dead	Alive	Dead	% Dead
25	138.0	1377.3	90.9	44.0	1405.7	97.0
50	10.3	1451.3	99.3	7.0	1368.0	99.5
100	4.7	1443.0	99.7	2.0	1441.3	99.9
0	1404.3	92.0	6.1	1380.0	90.7	6.2

C.—Replicated Tests Using Field Power Spray Equipment (Treated 2/1/50)

Gals. Spray per Acre	Mean No. Red Spiders per 100 (0.3 Sq. In.) Samples[1]					
	2/3/50			2/6/50		
	Alive	Dead	% Dead	Alive	Dead	% Dead
25	47.0	2774.7	98.3	13.7	2348.7	99.4
50	25.3	2533.3	99.0	14.3	2470.0	99.4
100	2.3	2882.7	99.9	0.3	2413.0	99.9+
0	2624.0	424.0	13.9	2554.0	589.7	18.8

[1] Population counts in all experiments made by selecting a heavily infested area on each leaf and extracting a 0.3 sq. in. leaf plug by means of a cork borer.

Preliminary tests consisting of non-replicated plots of 0.01 acre treated with a knapsack type sprayer operating in a pressure range of 30 to 50 pounds per square inch were conducted for the purpose of evolving a satisfactory method of making red spider mortality determinations. Results of a representative series of these preliminary tests are given in table 1A. An increase in mortality with increase in rate of application and elapsed time between treatment and evaluation was observed. The method of evaluation presented here appeared satisfactory for the purposes of these trials.

These effects were further tested in a series of replicated small plots using the same treatments

[1] *Sinox General*—Standard Agricultural Chemicals, Inc.
[2] Associate Entomologist.
[3] Plant Physiologist.

and methods of application as in preceding preliminary tests. Results obtained on these plots which were replicated 3 times are given in table 1B. These showed the same encouraging trends as were seen in the previous trials and the method of determining relative spider mortalities proved highly satisfactory from a statistical viewpoint.

Results of these preliminary trials were so promising that a series of field operation type plots were organized to test the practicality of the method and to obtain further comprehensive data. Large scale, replicated field plots were sprayed at a pressure of 250 pounds per square inch using a John Bean Model 404T sprayer equipped with fan type nozzles. Plots were 0.25 acre in size and were replicated 3 times. Rates of application were the same as those used in the preliminary hand treated plots. Variations in rates were obtained by allowing the pump pressure to remain constant and varying the rate of movement of the sprayer. Results of this final series of trials are reported in table 1C and offer conclusive evidence that 75 per cent dinitro ortho secondary amyl phenol in herbicidal concentrations effectively controlled red spider in Blakemore strawberries under weather conditions prevailing in this area in the winter of 1949–50.

Orlon Tent for Citrus Fumigation with Hydrocyanic Acid[1]

HAROLD R. YUST, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

A new synthetic fiber called *Orlon* has been reported to be more stable than nylon when exposed to sunlight and high temperatures. Nylon tents were first used in 1946 for citrus fumigation. Their initial tensile strength was much greater than that of cotton duck or drill in relation to their weight, but Yust *et al.* (1948) showed that nylon lost strength rapidly in roof exposure tests. A fumigation tent of Orlon cloth, made during the summer of 1949, is being tested for retention and durability in field fumigation of citrus trees with hydrocyanic acid gas. The Orlon cloth is a plain weave of continuous-filament, single-ply yarn. The fabric has a hard finish, and weighs approximately 3.94 ounces per square yard. The thread count is about 76 warp and 64 filling yarns per inch, and the thickness 0.0091 inch.

The quantity of hydrocyanic acid gas retained by *Orlon* and cotton tents on orange trees was determined in regular commercial field fumigations and in fumigations under two tree forms on grounds of the Whittier, California, laboratory of the Bureau of Entomology and Plant Quarantine. In the field, adjacent trees of about the same size were selected for each comparison and 16-cc. and 18-cc. schedules were used. Gas samples were taken from four locations under each tree at eight intervals throughout 45-minute exposures to obtain the average concentrations. Retention tests were also made in tents over tree forms of the same shape and with a volume of about 2000 cubic feet. In these tests differences in leakage due to unlike volume and surface area were eliminated. The cotton tents were of duck weave and in good condition, and the measurements over the tents were adjusted for shrinkage.

In the field tests the average concentration of hydrocyanic acid gas in four comparisons under dry conditions was 0.80 mg./liter with the *Orlon* and 0.90 mg. with cotton tents. When the tents were wet with dew the average concentrations were 0.99 mg./liter with *Orlon* and 0.93 mg. with cotton. In the form tests the average concentrations in three comparisons under dry conditions were 0.95 mg./liter with *Orlon* and 1.09 mg. with cotton. Air movement occasionally rippled the *Orlon* in these tests. In four comparisons under wet conditions the average concentrations were 1.39 mg./liter with *Orlon* and 1.31 mg. with cotton. When the tents were dry the average concentrations were higher under the cotton tents but when the tents were wet with dew the concentrations were higher under the *Orlon*. *Orlon* is similar to nylon in gas retention under wet and dry conditions, as shown by the results with nylon tents presented by Yust *et al.* (1948).

Orlon fabric has the advantage of being lighter than the cotton duck and drill in general use. It is not so strong as nylon of the same weight. Because of its smooth, hard finish and light weight, an *Orlon* tent is relatively easy to put over a tree. When used in a string of nylon tents the *Orlon* tent appeared to handle about the same as the nylon. Although the tent has not been in use long, it does not appear to shrink or stretch. Hydrocyanic acid gas has no apparent deleterious effect on the fabric. *Orlon* showed no evidence of breakdown after being buried in the soil for 3 months.

Orlon and nylon fabrics were tested for tearing strength by the ASTM (D39-39) tongue method. When exposed on the roof at the Whittier laboratory for about 10 months, *Orlon* lost little strength and nylon showed no strength. The tensile strength of nylon was lost much more slowly in field use than in roof exposure tests. After about two and a half seasons' use the strength of the warp from a nylon fumigation tent was 5.5 pounds and of the fill 4.5 pounds, as compared with a tearing strength when purchased of about 14 pounds for warp and fill. *Orlon* was superior to nylon in its resistance to sunlight and associated high temperatures. The durability of the *Orlon* tent will be further determined in commercial citrus fumigation.

LITERATURE CITED

Yust, Harold R., Ivan A. Welborn, Jr., and Howard D. Nelson. 1948. Nylon tents for fumigation of citrus. Calif. Citrog. **33**(9): 382, 405–6.

[1] Orlon is a trademark for an acrylic yarn and staple. Cloth for the experiments reported here was provided by the Duplan Corporation.

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Trends in Insect Control—1950

Every entomologist acquainted with the progress of the Science of Economic Entomology will admit, I believe, that the public has become more insect conscious than ever before and that people tend to consider the new insecticides, especially the new organic chemicals, a panacea for all our insect problems. In general, entomologists have resorted to the "line of least resistance," have forgotten to emphasize good practices, and have accepted the erroneous thought that control, regardless of cost, is a more important factor than the economy of control. I challenge this thought. High prices for farm products may be here today but what may they be tomorrow?

We progress through the years, but may we not have forgotten, in our enthusiasm for the new insecticides, the basic principles of insect control—good practices—*preventive entomology.*

After my tutelage under the grand old man—Stephen A. Forbes, and then Francis M. Webster, I became a staunch advocate of preventive entomology. They showed me the way. They impressed upon me the value of "farm" practices as the least expensive and most helpful of all insect preventives.

At the present time we are faced with high prices for farm products. Insecticide treatments produce results and perhaps under present economic conditions we can afford to spend money for such treatments, even on extensively grown, low-value crops. What about five years hence when the value of farm products may reach a low level? Can we profitably use expensive insecticide treatments for low value crops? I don't think so.

My sermon is to re-emphasize the importance and value of good "farm" practices. After the date of sowing wheat was definitely established as the major factor in Hessian fly control, it took ten or more years of publicity and demonstration to secure its adoption. Until 1930 we experienced serious losses from Hessian fly about every two or three years, but since the general adoption of the so-called fly-free date, damage has been negligible. Furthermore, agronomists recognize the "fly-free" date as the best date to sow wheat regardless of the Hessian fly.

While considering the value and necessity of good practices, we must not forget the value and essentiality of insecticides, but at the same time let us remember that good farm practices, or orchard practices, or greenhouse practices, or forest practices, or animal husbandry practices, and other good practices, regardless of the industry, are essential for securing effectiveness of insecticides. For example, what good entomologist would recommend chemical treatment for termites without emphasizing the necessity of good construction replacements. Who would make community fly control recommendations without emphasizing the necessity of good sanitation practices?

Chemical controls will always be essential but in the same breath let us state that good practices—agronomic, horticultural, animal husbandry, home, and others, are just as essential, or more so, as the use of insecticides. Chemical control is expensive but essential, and the duty of the entomologist is to secure pest control at the least expense, and to give more consideration to good growing and sanitation practices.

J. J. DAVIS

OBITUARIES

Bevy Marshall Gaddis
1891-1949

Bevy Marshall Gaddis was born May 20, 1891 on a farm near Suches, Union County, Georgia. He was reared on this farm and attended rural schools until the time he entered high school at Blairsville, Georgia. His early career from 1909 to 1916 included four years of study at the Smith Georgia State Agricultural College, Douglas, Georgia, where he left as an honor graduate, and several years of teaching in the Georgia public schools.

From 1916 through 1921 he served with the Georgia State Board of Entomology as research assistant engaged in breeding pest-resistant varieties of cotton, and in the investigation of cotton, tobacco, and truck crop insects including the cotton boll weevil.

In 1922 he became a nursery inspector for the State and in 1925 was promoted to chief nursery inspector directing all nursery inspection activities and the enforcement of State quarantines. In the period 1927 to 1929 he also acted as a collaborator, without pay, with the U.S.D.A., Federal Horticultural Board, supervising the local enforcement of the regulations pertaining to the Narcissus Bulb Quarantine No. 62.

With the beginning of the Mediterranean fruitfly campaign in Florida he was selected by the Georgia State Board of Entomology to be in charge of the field administration of the State Mediterranean fruitfly quarantine in that State until such time as a Federal quarantine should be promulgated. He was appointed May 8, 1929 as agent, U.S.D.A., Plant Quarantine Control Administration and assisted in the field enforcement of the Federal quarantine outside the State of Florida. He was largely responsible for the planning and directing of road traffic inspection along the Georgia-Florida line including the supervising of the difficult and complicated task of moving into safe and orderly distribution by rail, truck, and boat, the citrus and other fruitfly hosts from the heavily productive area quarantined in Florida. On May 1, 1930, he received permanent Civil Service appointment as associate plant quarantine inspector. During 1931 his services were extended to include assisting in the fruitfly quarantine work and field inspection in the State of Florida.

At the close of the Mediterranean fruitfly campaign he was transferred in July 1931 to the Mexican Fruitfly Project with headquarters at Harlingen, Texas.

In April 1934 during the unusual grasshopper outbreak in progress at that time in western and midwestern states, he was placed in field charge, under the direction of Dr. P. N. Annand, of the procurement, routing and delivery, and mixing of bait materials and the supervising of the employees engaged in these activities on the Federal-State Grasshopper Control Project with headquarters at Minneapolis, Minnesota. In October 1934, he was transferred to Washington, D. C., to head the Division of Domestic Plant Quarantines, and he filled this position until his death.

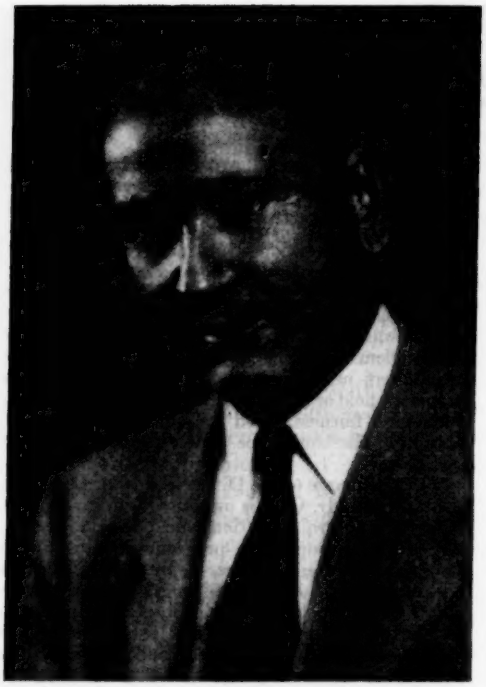
In administrative matters he combined an exceedingly broad grasp of general relations and values with an eminently practical understanding of intimate details and procedures. In this he was aided by an unusual memory. He was well versed from a practical standpoint in the management of crop and farm procedures. In early years he disliked to speak in public but he developed into a convincing speaker and through his intimate knowledge of his subject was able to present plans and viewpoints effectively in meetings and conferences. Further, as a cooperator, he was quick to grasp and appreciate the needs and problems of other interests, and could thus plan with others mutually workable programs. In this important field of Federal-State relations, his ability, leadership, fairness, good sense, and sound judgment won the confidence and respect of the other participants.

While in charge of the Division of Domestic Plant Quarantines, Mr. Gaddis organized and carried out survey and control operations and associated regulatory work on cooperative programs relating to the golden nematode; the grasshopper and Mormon cricket; cinch bug; white-fringed beetle; sweetpotato weevil; mole cricket; dog fly; the phony peach and peach mosaic diseases; and the citrus canker disease. He planned, directed, and cooperated in surveys for numerous pests, including the Egyptian alfalfa weevil, *Parlatoria Chinensis* scale, Oriental fruit moth, and potato rot nematode. His divisional responsibilities included the direction of transit inspection and other means of enforcement of Federal domestic plant quarantines, such as those relating to black stem rust and white-pine blister rust, and cooperation with the states in enforcement of state plant quarantines and nursery inspection requirements. His philosophic and practical knowledge in the quarantine field permitted important contributions to the initiation and evaluation of Federal domestic and state quarantines. Upon assuming leadership of the Division he continued revision and issuance of summaries of state and territorial requirements and terminal inspection which contributed greatly to dissemination of information concerning regulations on plant movement and consequently more general compliance with them by shippers and common carriers.

He appreciated the need for the counsel and assistance of chemists, physicists, engineers, and mechanics in the basic work of entomologists and plant pathologists and he sought their advice in planning and effecting large scale control operations. Among the numerous endeavors of a mechanical nature with which he was concerned, three items are cited which are typical of his range of interest:

(1) He was keenly interested in the further adaptation of the airplane in pest control, cooperating with other field workers concerned; he assisted in the demonstration of the practical value of the airplane in the distribution of poison bait for the large scale control of grasshoppers in the epidemic years of the late 1930's. More recently he was concerned with the development of airplane sprays in the control of the white-fringed beetle.

(2) A natural mechanical ingenuity led him to take intensive interest in developing and



Bevy Marshall Gaddis

adapting special devices in the construction of spray equipment; an example was the development under his direction of an oscillating-delivery device for rapid, uniform, and economical application of concentrated spray in connection with a sprayer adapted for use on white-fringed beetle control.

(3) He had a wide interest in the fumigation and other treatments of commodities, soil, etc., as related both to practical pest control methods and to the movement of articles regulated by quarantines; under his direction an applicator for the even distribution of fumigants in the soil to destroy nematodes was adapted so as to be directly tractor-borne.

In the field of constructive quarantine planning, perhaps his most valuable contribution lay in activities promoting the adoption of uniformity and simplicity in state quarantines. He was quick to visualize clearly the advantages of uniformity in these measures, not only as a means of reducing their numbers and simplifying their terms, but also of avoiding an unnecessary variety and complexity, and thus bringing a welcome relief to nurserymen, shippers, quarantine inspectors, and public carriers. The state quarantine officials, especially in states in which there have been no cooperative pest-control programs in progress, and the nursery interests were appreciative of his efforts and recognized the leadership and assistance that he supplied.

The career of B. M. Gaddis provides a striking example of accomplishment reached by an aggressive and persistent personality endowed with natural talent and sterling qualities. His life, begun in comparative obscurity, expanded constantly with the strenuous years until his endeavors attained a broad, national scope wherein, through his ability and qualities of leadership, he could make distinctive contributions in the field of public service. He was recognized widely for his keen intellect, his outstanding faculty for quickly analyzing problems and his ability in promptly arriving at satisfactory solutions in relation thereto. The readiness with which he could plan, organize, and promptly start project activities, the emergency nature of which required immediate action, contributed materially to his leadership in pest control work. To the detriment of his health he was untiring in his efforts to conduct operations efficiently.

A man of many lively interests and with an intensely human and likable make-up, as well as a fine sense of humor, he enjoyed a wide friendship the country over, not only among his immediate colleagues and Bureau workers, but in the whole range of state and Federal pest control officials. One suspects that a prominent element in this ability to create and maintain friendships was his quick sympathy with misfortune and an innate readiness to aid others wherever he could. He always had the interests of both his professional work and of the employee at heart.

Among avocational interests, Mr. Gaddis was an enthusiastic amateur archeologist. His collection of minerals, Indian pottery, weapons, tools, and artifacts was both extensive and varied. His interest in collecting also extended into the field of old American furniture, silver, and glass. He was an ardent gardener and was interested in both cultivated and native plants.

In religious and social affairs, he was a member of the Unitarian Church; he was an active member of the organization of professional employees U.S.D.A.; and belonged to the American Association of Economic Entomologists and the American Phytopathological Society.

On August 22, 1949, B. M. Gaddis suffered a cerebral hemorrhage at his home, 6713 N. Washington Blvd., Falls Church, Virginia, as a result of which he passed away on August 25. He was interred August 27 in National Memorial Park near Falls Church.

He is survived by his widow, Mrs. Claudelle Lewis Gaddis and their three minor children, Marshall L., Paul L., and Earl L. Gaddis of Falls Church, Virginia; also by a son, Dr. Don A. Gaddis, a practicing physician, Stanton, Texas, and daughter, Mrs. G. E. (Joyce Gaddis) Kardos, of Charlottesville, Virginia, both children by a former marriage to Miss Effie Cowart, now resident in Arlington, Virginia; and by three brothers, M. F. Gaddis, Quitman, Georgia; M. W. Gaddis, Panama City, Florida; and Carl H. Gaddis, Lafayette, Louisiana.

P. N. ANNAND
ROY G. RICHMOND

Charles Taylor Vorhies
1879-1949

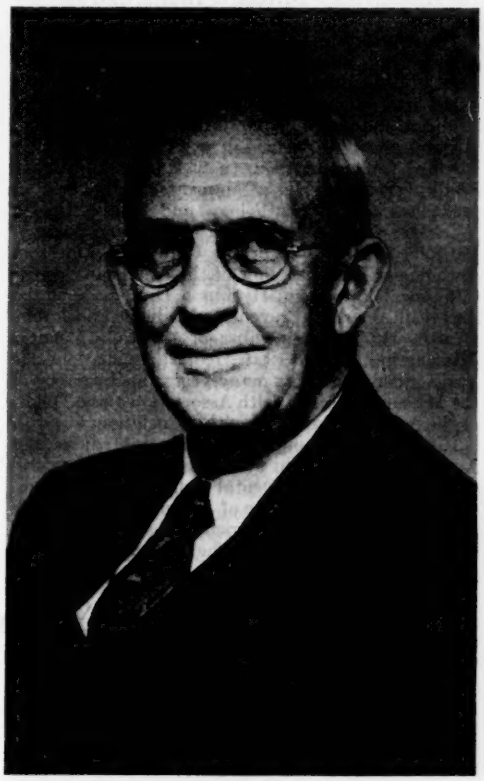
Charles Taylor Vorhies, head of the Department of Entomology and Economic Zoology at the University of Arizona, died on March 10, 1949 in Washington, D. C., where he had gone to attend the National Wildlife Conference.

Charles Taylor Vorhies was born on September 7, 1879 in Henry County, Iowa. His parents were Daniel and Rachel Elizabeth (Taylor) Vorhies. He attended public grade and high school in that state and graduated from Iowa Wesleyan College in 1902 when he received the bachelor of science degree. He was an instructor in biology at Iowa Wesleyan College from 1902–1904. He was an assistant in zoology at the University of Wisconsin from 1904 to 1908 and received the Ph.D. degree from this university in 1908, being one of the first to receive this degree from the Department of Zoology. While at Wisconsin he studied the bird and insect life in the nearby marshes. The results of this work is recorded in several papers on Trichoptera.

He was professor of zoology and botany at the University of Utah from 1908 to 1915 and acting dean of the medical school of the same institution from 1911 to 1913. He was an instructor in entomology at Cornell University in the summer of 1915. He was assistant professor of biology at the University of Arizona from 1915 to 1916, and professor of zoology from 1916 to 1918. He was transferred to the Agricultural College and became professor of entomology and entomologist of the Arizona Agricultural Experiment Station from 1918 to 1933. He also served as acting dean of agriculture, acting president and administrative advisor at various times during this period. From 1933 until the time of his death he was head of the department of entomology and economic zoology and professor of zoology in the College of Agriculture of the University of Arizona, and economic zoologist of the Agricultural Experiment Station. In Arizona Dr. Vorhies published numerous papers dealing with entomology, mammalogy, herpetology and ornithology. A complete bibliography of his published work is given in the Journal of Wildlife Management, Vol. 14, Number 1, January 1950.

Dr. Vorhies was much interested in the conservation of wildlife and natural resources of all kinds and gave this work his active support. As a teacher he made extensive use of animal and plant life as it occurs in nature. He emphasized field observations by the use of natural materials as found in the desert rather than books, although books which were helpful to this end were used. He did not feel the subjects which he taught were of greater importance than other subjects which his students might be taking at the same time.

He was a fellow in the American Association for the Advancement of Science (president, Southwestern Division 1933), member of the American Ornithologists Union, Utah Academy of Science (president in 1913), Ecological Society of America (president in 1939), American Society of Mammalogists and the Cooper Ornithological Club.



Charles Taylor Vorhies

He was a vice-president and chairman of the committee on Conservation Education of the National Wildlife Federation. He was a member of the American Society of Ichthyologists and Herpetologists. He helped found the Arizona Game Protective Association, the Tucson Natural History Society, and the Arizona Wildlife Federation which he served as secretary-treasurer for many years. He was a member of Sigma Xi, Phi Kappa Phi, Phi Delta Theta and a member of the Methodist Church

He was preceded in death by his first wife, Marie Isabel (Tuttle) Vorhies. He is survived by a son, Charles Tuttle Vorhies and his wife Georgia Ann (Clark) Vorhies.

LAWRENCE PAUL WEHRLE

Brayton Eddy

Brayton Eddy, in charge of insects and reptiles in the Bronx Zoo, died July 17 of a pulmonary embolism. He was 51 years old. Mr. Eddy was noted among entomologists largely for his ability to write popular articles about insects without cheapening them by trying to bring them down to the popular level. He was able to write strictly scientific truth in a form which was interesting to the reader who might not be trained in the subject discussed and was still eminently acceptable to the professional entomologist or biologist.

Charles Frederick Adams

Dr. Charles Frederick Adams, Acting Director of the Missouri State Division of Health, died January 21, 1950.

Dr. Adams was born April 4, 1877, in Atherton, Missouri. He married Miss Irma Comstock of Jefferson City, Missouri, in 1947.

He had a most active professional career in medicine and teaching and in the natural sciences.

He received his medical degree from Kansas City Medical College in 1902, (now Kansas University Medical School). His attainments in the field of medicine were in Pathology and Public Health Work. He was a Diplomate of the American Board of Pathology, a member of the College of American Pathologists, and a Fellow of the American Society of Clinical Pathology. He was a Diplomate of the American Board of Preventive Medicine and Public Health. He was a member of the Cole County, Missouri and the American Medical Associations. He was a member and for many years the Secretary of the Missouri Public Health Association and a Fellow of the American Public Health Association.

His work in teaching concerned both Medicine and Agriculture. He taught at the Kansas City Medical College, Kansas City Dental College, Chicago University and the University of Arkansas where he was the Dean of College of Agriculture and Director of the Experiment Station. In the Natural Sciences he was very active in Entomology being especially interested in work with mosquitoes and flies. He was a Fellow of the Entomological Society of America and a member of the Association of Economic Entomologists. He published original studies in the Taxonomy of insects.

For a twelve year period prior to 1925, he was actively engaged in farming and dairying in the vicinity of Atherton, Missouri. He was Director of Laboratories of the Missouri State Division of Health, having been in that position from 1934. For some years, he was pathologist at St. Mary's Hospital in Jefferson City, carrying on this activity in addition to his regular work as Director of Laboratories of the State Division of Health. From 1927 to 1934, he was Director of Laboratories for the Indiana State Board of Health.

In June 1949, Dr. Adams was appointed as Acting Director of the Division of Health of Missouri.

On December 15, 1949, he entered the Menorah Hospital, Kansas City, Missouri for herniotomy with satisfactory recovery. On December 29, due to the formation of a blood clot, his left arm was removed. He returned to his home in Jefferson City on January 14, 1950, and resumed some of his work the following week. On January 21, 1950, his death occurred following a cerebral hemorrhage.

Floyd F. Bondy

Floyd F. Bondy, a member of the American Association of Economic Entomologists, died on July, 19, 1950, at Florence, South Carolina, and was buried at Bluefield, Virginia, on July 22.

Mr. Bondy was a specialist in the control of cotton insects and had been engaged in research on the control of these insects as a member of the Bureau of Entomology and Plant Quarantine for the past 33 years.

During this period Mr. Bondy was stationed at Tallulah, Louisiana, and at the Pee Dee Experiment Station, Florence, South Carolina and at other stations in the cotton-growing areas. Much of his work was done in cooperation with state and local organizations engaged in similar studies.

Mr. Bondy was born on October 7, 1894, at New Roads, Louisiana where he received his early education. In 1917 he received the degree of Bachelor of Science from Louisiana State University where he received his early training in Entomology.

Mrs. Eleanor McCall Bondy, his wife, who lives in Florence, and two sons residing in Texas, survive.

Harcout Alexander Morgan

Dr. Harcourt Alexander Morgan died at his home in Belfast, Tennessee on August 25, 1950.

Dr. Morgan was born in Kerrwood, Ontario, on August 31, 1867, was educated in Ontario Agricultural College, the University of Toronto and Cornell University. He became a citizen of the United States in 1891. He spent some ten years in Louisiana in Entomological work and from 1905 until 1933 was at the University of Tennessee as entomologist, Dean and President.

From 1933 to 1948 Dr. Morgan was connected with the Tennessee Valley Authority.

Dr. Morgan was second vice-president in 1906 and president of the American Association of Economic Entomologists in 1907.

A more adequate account of his career as an entomologist will be published if it can be secured.

BOOK REVIEW

SUBTROPICAL ENTOMOLOGY, by Walter Ebeling. Lithotype Process Co., San Francisco, Calif. 1950, 719 pp., with 570 text figures and 1030 references. Price $8.00.

The field of subtropical entomology has received a great deal of attention for many years, especially with regard to citrus pests. The publication of Quayle's "Insects of Citrus and Other Subtropical Fruits" in 1938 provided an excellent account of that portion of the field. So many advances have been made since that date, especially in the materials, equipment and methods of control, that a real need has arisen for an up-to-date account. The present volume serves that purpose.

"Subtropical Entomology" is a far too broad title for the subject matter that is presented in this volume. It is devoted entirely to fruit insects and among these only citrus is dealt with on a world-wide basis, the remainder comprising mainly those occurring in California. There is no mention of pests of tea, coffee, sugarcane or of insects affecting the health of man and animals, to mention only a few, that are of importance in the field of subtropical entomology.

This book comprises the subject matter included in a course on subtropical fruit insects presented at the University of California at Los Angeles, and the emphasis on California problems is therefore understandable. The first three chapters deal with the "Origin and Scope of Applied Entomology," "Morphology and Metamorphosis" and "Classification." The reviewer feels that the last two have no place in a book on applied entomology, though admittedly included in past publications of a similar nature. An informative chapter is that on "Organization and Legislation in Entomology" that gives an account of the development and accomplishments of the federal organizations and a similar account of the various California organizations engaged in research, regulatory and control activities.

The twelve following chapters covering 216 pages give an extended and thorough account of the various aspects of chemical control, including the chemistry of the new insecticides, formulations, methods and equipment for application and experimental design and evaluation. The chapter on oil sprays with its detailed discussions of various types of plant injury caused by various oils when applied to citrus trees, is of special interest, and reflects the author's long research experience in this field. This section will be of special value to younger workers who feel the need for a readily accessible summary of the present day knowledge in this rapidly changing field. In reading this book, one is impressed with the great advances that have been made during the past 10 years as compared with preceding periods.

The chapter on biological control includes a short discussion on host relationships, the theoretical basis of biological control, some biological phenomena affecting colonization and establishment, the effect of insecticides on populations of natural enemies and concludes with a review of accomplishments in biological control in California since its inception in 1888.

Citrus insects and their control are dealt with in considerable detail in two chapters covering 211 pages. Extended accounts, with maps, are given of the citrus-producing countries of the world, with a listing of the pests occurring in each country. This information is exceedingly useful, though the arbitrary rating of the major pests in exact order of importance in each country or section may be questioned, as sufficiently detailed information is not available from most countries to permit such an exact evaluation.

The final nine chapters deal with pests of grape, walnut, almond, pecan, fig, olive, avocado, date and miscellaneous fruit pests.

The book concludes with a list of 1032 literature citations and an adequate index.

Typographical errors are relatively few and errors of fact infrequent. The author has called the reviewer's attention to errors in the structural formulae of the pyrethrins (p. 134), 4,6-dinitro-o-cresol, 2,4-dinitro-6-cyclohexylphenol (p. 162) and propylene and styrene (p. 167). These will be corrected in the second printing that will appear in the near future. A list of errata covering other typographical errors will be included. Aside from these chemical formulae, mention may be made of the reference on page 323 to *Cryptochaetum iceryae* as a parasite of the vedalia beetle, rather than of the cottony cushion scale, and on page 339 of the mite, *Tyroglyphus phylloxerae*, as peing imported for control of the cabbage worm. This is evidently intended to refer to *Apanteles glomeratus*, as *Tyroglyphus* was shipped from the United States to France in 1873 as an enemy of the grape phylloxera.

Reproduction of this volume is by the lithoprint process and the paper used is of good quality. The binding, while pleasing to the eye, is not sufficiently strong for a volume of this size and weight. The text matter is clear and the figures, both line and photographic, are unusually good. Special mention should be made of the large number of photographs by R. J. Pence, many of which are of exceptional quality and have reproduced well.

The author is to be congratulated upon an excellent account of the pests of fruit, within the limitations mentioned above, and of methods employed in their control. The book will be a valuable source of information and guidance of all workers in this field.

—C. P. CLAUSEN

Proceedings of the Thirty-Fourth Annual Meeting
Pacific Slope Branch
American Association of Economic Entomologists
Santa Cruz, California, June 14, 15, and 16, 1950

The thirty-fourth annual meeting of the Pacific Slope Branch of the American Association of Economic Entomologists was held in Santa Cruz, California, June 14, 15, and 16, 1950. The officers during the meeting were: H. M. Armitage, *Chairman;* Ed. H. Littooy, *Vice-Chairman;* Leslie M. Smith, *Secretary-Treasurer.* The chairmen of the various committees were: program, *S. F. Bailey;* arrangements, *Laurel G. Smith;* arrangements for ladies, *Mrs. E. G. Linsley;* registration, *J. K. Primm;* operations, *D. T. Rayner*; press, *A. J. Flebut;* constitution, *Roy E. Campbell;* resolutions, *E. J. Steinhaus;* nominations, *J. N. Roney;* membership, *E. O. Essig;* advanced meeting schedule, *A. F. Kirkpatrick;* and, auditing, *C. E. Graves.* Acting chairmen at various times during the meetings were: *H. M. Armitage, E. H. Littooy, S. F. Bailey,* amd *Laurel G. Smith.*

The assembled entomologists were pleased to hear greetings and comments from C. P. Clausen, our national president; followed by a response from R. E. Campbell, First Vice-President. Forty-six papers were delivered, including several invitational papers. Walter Carter made an excellent presentation of the progress of the research on the Oriental fruit fly in the Hawaiian Islands, C. J. Carey discussed legal aspects of insect control; M. P. Jones discussed extension entomology; A. J. Cox discussed the insecticide hearings conducted in Washington; and H. P. Lanchester delivered a paper on statistics as applied to wire worm research.

There was an informal get-together Tuesday evening and a banquet Thursday evening followed by an entertainment and dancing. Sightseeing tours and special luncheons were arranged for the ladies.

On Wednesday evening the Branch met to hear a discussion of Extension and its relation to industry, research, specialists, etc. This session was under the chairmanship of H. F. Madsen and M. P. Jones. Speakers at this session were Ed Swift, Don Mote, H. F. Madsen, M. P. Jones, C. A. Ferris and Laurel Smith.

At a preliminary business meeting Wednesday morning, R. E. Campbell, chairman of the committee on constitution, distributed copies of a proposed constitution for the Pacific Slope Branch.

At the business session, Friday afternoon, the members discussed the proposed constitution. A new name for the Branch was considered, but the members voted unanimously to retain the name Pacific Slope Branch. The members were unanimously in favor of having a constitution. After considerable discussion of the new constitution from the floor, a motion was passed requesting the incoming president to appoint a committee to study and rewrite the constitution and that copies of the revised constitution be mailed to members of the Branch before the next meeting of this Branch.

Chairman Armitage called for the following reports:

Report of the Membership Committee

The Pacific Slope Branch has added 11 new members during the past year.

E. O. Essig, *Chairman,*
S. C. Jones
D. F. Palmer

Treasurer's Report

	Credits	*Debits*
Balance in Treasury, June 8, 1949	$449.66	
Typing programs, 1949		$ 15.40
Postage on programs, 1949		15.82
Printing programs, 1949		86.52
Registration fees, 1949 meeting	251.00	
Membership letters		6.21
Telephone		2.06
Postage		6.00
Printing of checks		1.35
Printing announcements of meeting, 1950		30.90
Printing programs, 1950		128.75
	$700.66	293.01
Balance in Treasury June 13, 1950		407.65
	$700.66	$700.66

Leslie M. Smith, *Secretary-Treasurer*

Report of the Auditing Committee

We have examined the records and receipts of the Secretary-treasurer and find them correct and in agreement with the financial statement.

C. E. Graves, *Chairman*
Allen Lemmon
A. E. Pritchard

Report accepted by membership.

Report of Committee on Advanced Meeting Schedule

The committee proposes the following meeting places:

1951, Seattle, Washington, meeting at the University of Washington; headquarters, Hotel Edmond Meany
1952, Santa Barbara, Calif.
1953, San Francisco Bay area
1954, Sun Valley, Idaho
1955, Pasadena, Calif.

A. F. Kirkpatrick, *Chairman*
L. R. Gardner
D. C. Mote

The membership unanimously approved Seattle for the 1951 meetings.

Inasmuch as the Entomological Society of British Columbia plans to meet in Vancouver on June 14, 15, and 16, 1951, a motion was passed instructing the secretary of the Pacific Slope Branch to invite the Entomologist Society of British Columbia to meet with the Branch in Seattle.

Report of the Committee on Resolutions

The Committee on Resolutions presented several resolutions and these were considered individually by the membership. The resolutions adopted by the membership were:

Resolution 1

Whereas the members of the Pacific Slope Branch of the American Association of Economic Entomologists, in attendance at the 34th annual meeting of this branch held in Santa Cruz on June 14, 15 and 16, 1950, have enjoyed a very profitable and successful meeting, and are deeply grateful to

various agencies and organizations which have made this possible, be it therefore resolved that thanks be extended to the various committees having to do with the organization and conduct of these meetings, and especially

To the Committee on Arrangements, consisting of Laurel G. Smith, C. O. Persing, S. W. Strew, G. S. Hensill, and R. O. Hassarud, for their careful and thorough planning.

To the Program Committee, consisting of S. F. Bailey, E. Gorton Linsley, L. C. Glover, J. K. Holloway, and H. H. Keifer, for their successful efforts in arranging the very interesting and valuable program.

To the Committee on Arrangements for Ladies, consisting of, Mesdames E. G. Linsley, J. K. Primm, H. M. Armitage, Ed Littooy, and Roy E. Campbell.

To the industrial and commercial concerns for financing the costs of the meeting room, the Tuesday evening get-together, the delightful entertainment, and the dance orchestra.

To the management of the Casa del Rey Hotel for their courtesies in accommodating the members in numerous ways.

Resolution 2

Be it resolved that the parent Association devise and set up means of processing applications for membership so that the present practice of voting in new members only at the time of the annual meeting be supplemented by taking in new members immediately.

Resolution 3

WHEREAS, the present Executive Committee of the American Association of Economic Entomologists is, by constitutional provision, made up of the President, Vice-President, Secretary, President of the preceding year, and five members elected at large, and

WHEREAS, such provision does not assure proper geographical representation, often placing the preponderance of representation in one or at most two of the four major branches; now, be it

Resolved that in order to give more nearly equal branch representation on such committee, that the present Executive Committee be requested to take such steps as may be necessary to revise or amend the constitution so as to provide that in place of elected members-at-large there be substituted the Chairman of each of the branches of the Association; and be it further

Resolved that if this resolution meets with the favor of the members in attendance at the present meeting of the Pacific Slope Branch in session at Santa Cruz, California, June 14 to 16, 1950, that copies be mailed by the Secretary of the Branch to the President and to the Secretary of the parent organization and also to the Secretaries of the various branches soliciting the latter's approval and support of this action.

Resolution 4

WHEREAS, there has recently been presented to the members of the Association the matter of approving or disapproving the application of a small group of States for permission to withdraw from the respective geographical branches with which they have been associated in the past and establish a new branch on the basis of a rather restricted field of mutual entomological interest, and

WHEREAS, in breaking up into such small units the Association would tend to lose its real value which under the present arrangement of large geographical branches provides opportunities for wide personal contacts and exchange of information and experience among workers in related rather than restricted fields; now therefore, be it

Resolved that the Pacific Slope Branch go on record as disapproving in principle the establishment of numerous small branches within the Association and as approving as close adherence as possible to the present larger geographical branches; and be it further

Resolved that a copy of this resolution be forwarded to the President and Secretary of the parent Association and to the Secretaries of all branches.

Resolution 5

WHEREAS, the area embraced by the membership of the Pacific Slope Branch of the American Association of Economic Entomologists involves such a substantial portion of the entire agricultural economy of the nation as a whole, it is essential that ways and means for determining safe limits for contamination by economic poisons in food products of this region be established, and

WHEREAS, the Federal Food and Drug Administration has brought this matter to a head in the present residue tolerance hearings, and

WHEREAS, the rapid developments of new agricultural chemicals indicates that many of these will appear as contaminants in foodstuffs, and

WHEREAS, at present there is a total lack of facilities to carry on such investigations in this region; therefore, be it

RESOLVED that the Chairman be instructed to appoint a committee representing interested organizations and industries whose purpose would be to consider ways and means of assembling information, planning investigations, and establishing any necessary laboratories to carry on investigations in this field.

Resolution 6

Resolved that the authorship of articles submitted for publication in the JOURNAL OF ECONOMIC ENTOMOLOGY not be arbitrarily restricted to member entomologists alone, but that any member author shall be allowed the prerogative of including coauthorship of scientists or other cooperators in corelated fields of research as well as students of entomology enrolled in educational institutions.

Resolved that a copy of this resolution be forwarded to the President, the Secretary, and to the Editor of the JOURNAL OF ECONOMIC ENTOMOLOGY, and to the Secretaries of each of the several branches.

Resolution 7

Resolved that a committee be appointed by the Chairman to investigate the following:

(1) the most desirable month of the year to hold the meetings of the Pacific Slope Branch;

(2) appropriate methods of maintaining and improving the quality of papers presented before the Pacific Slope Branch meetings;

(3) the most desirable arrangement for presentation of the papers at the Pacific Slope Branch meetings, with consideration for provision for supplementary meetings and symposia on special subjects;

(4) and that a ballot incorporating all such items be submitted to the membership of the Pacific Slope Branch;

(5) the committee shall report on the results of the balloting at the next meeting of the Pacific Slope Branch.

Respectfully submitted,

EDWARD A. STEINHAUS, *Chairman,*
Resolutions Committee
CARL D. DUNCAN
A. F. SWAIN

REPORT OF THE NOMINATING COMMITTEE

The Nominating Committee nominates officers for 1950–1951 as follows:

Chairman, E. H. LITTOOY
Vice-Chairman, GLEN CARMAN
Secretary-Treasurer, LESLIE M. SMITH

Nominating Committee
J. N. RONEY, *Chairman*
E. T. DOYLE
A. W. CRESSMAN

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Anderson, Lauren D.
Anderson, L. E.
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Ash, Al
Atkins, Larry

Bahme, Richard B.
Bailey, Stanley F.
Barnard, C. O.
Barron, F. Ray
Bartlett, Blair R.
Bartges, Rex J.
Bashor, E. F.
Bayha, K. W.
Besler, William J.
Bodine, E. W.
Boissonou, C. J.
Bonnell, Dan
Borden, A. D.
Bowen, Charles H.
Boyce, A. M.
Brant, Ralph L.
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Burnside, W. H.
Bussart, J. E.

Campbell, Roy E.
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Carman, Glen
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Carter, R. Duncan
Carter, Walter
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Frazier, N. W.
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Gibson, Lester H.
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Glover, Leon C.
Goldsworthy, Edward A.
Graves, C. E.
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Gray, Henry E.
Griffin, Robert H.

Hamsher, C. A.
Hansberry, Roy
Hansen, James W.
Hanson, Arthur J.
Hassler, Karl
Hatch, F. W.
Hawthorne, Ronald
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